

Feasibility Study of the Contaminated Groundwater
at the CPS Chemical/Madison Industries Site
Old Bridge Township,
Middlesex County, New Jersey

DRAFT REPORT

Submitted to:

U.S. Environmental Protection Agency
Region II
26 Federal Plaza
New York, New York 10278

June 30, 1989



INTRODUCTION

The remedial investigation and feasibility study (RI/FS) process is the methodology used by the Superfund program to characterize the nature and extent of risks posed by uncontrolled hazardous waste sites, and to evaluate potential remedial options. The RI/FS process was designed to be a flexible one, responsive to site-specific needs and concerns. This draft report presents the FS performed for the CPS Chemicals/Madison (CPS/Madison) Industries site.

The CPS/Madison site is located in Old Bridge Township, Middlesex County, New Jersey. The site has been the subject of investigations, study, and litigation for approximately 20 years. Many of the investigations have attempted to characterize (to varying degrees) the nature and extent of site contamination; some studies have resulted in proposed options for site remediation. In 1988, the New Jersey Superior Court directed the installation of a groundwater recovery system, relocation of Pricketts Brook, and treatment of recovered groundwater (in conjunction with Madison Industries process wastewater) with effluent discharge to the local sewer authority.

STET ← The U.S. Environmental Protection Agency (EPA) directed the preparation of this FS; with the assumption that the numerous studies and reports compiled by previous investigators would provide the information normally collected during an RI. After review of the available documents, however, it was apparent that some areas usually addressed during a traditional RI had not been investigated. For example, ~~a comprehensive and detailed site characterization~~ ^{has} never been ^{completed}, and a baseline risk assessment had not been performed. Chapter 1 of this FS ^{Report} presents ~~this information~~ in greater detail than would be found in a

a detailed
characterization and
baseline risk
assessment.

traditional FS because the analyses are being presented for the first time.

Remedial action planning for a specific area (operable unit) of a larger site is allowed under the National Contingency Plan. The operable unit addressed in this FS is contaminated groundwater.

The information and documents that were the basis for this FS were provided by EPA, the New Jersey Department of Environmental Protection, and the U.S. Geological Survey.

Inconsistencies and incomplete information were found when reviewing the reports. Where assumptions were made because of informational deficiencies, the assumptions were noted in the report.

This report consists of four chapters:

- Site Characterization
- Identification and Screening of Technologies
- Evaluation and Selection of Process Options and the Development and Screening of Alternatives.
- Detailed Analysis of Alternatives.

This FS Reports addresses the contaminated groundwater as ~~the~~ Operable Unit I.

→ What was done about it? Where are such inconsistencies. Should this be mentioned here? Inconsistencies should be ID + resolved?

1. SITE CHARACTERIZATION

1.1 SITE BACKGROUND

1.1.1 Site Description

The CPS Chemical Company ~~CPS~~ ^{Industries} /Madison ^(CPS/Madison Site) site is located in Old Bridge Township, Middlesex County, New Jersey (40° 26'00" north latitude and 74° 18'45" west longitude), as shown in Figure 1-1. The site is approximately 21 acres and is located off of Waterworks Road, 4 miles south of the city of South Amboy and 2.5 miles north of the city of Old Bridge. Several other industries, including the Jersey Billets Division of Easco, Lionett Oil Recovery, BG&M, and Forte Pallet, are located near the site. ~~Of particular interest is the~~ ^{is located} Evor Phillips Superfund site directly upgradient (northeast) of the CPS/Madison site. Two large well fields, Sayreville and Perth Amboy, located northwest and southwest of the site, supply drinking water to the surrounding communities. Adjacent to the well fields are the Sayreville Recharge Ponds, Tennent Pond, and Pricketts Pond, which were excavated to induce recharge to the groundwater to increase the production of the water supply wells.

~~The CPS/Madison site is ranked tenth on the National Priorities List (NPL) and fourth among NPL sites in New Jersey.~~
The site includes two operating facilities, CPS and Madison Industries (formerly Food Additives), which share a common property boundary. Figure 1-2 shows the location of the site. CPS began operations in 1968 and manufactures organic chemicals (flocculants, dispersants, and coagulants) that are used for water treatment processes. In addition, CPS recovers solvents and other organic chemicals by distillation. Madison Industries has been in operation since 1967 and produces inorganic

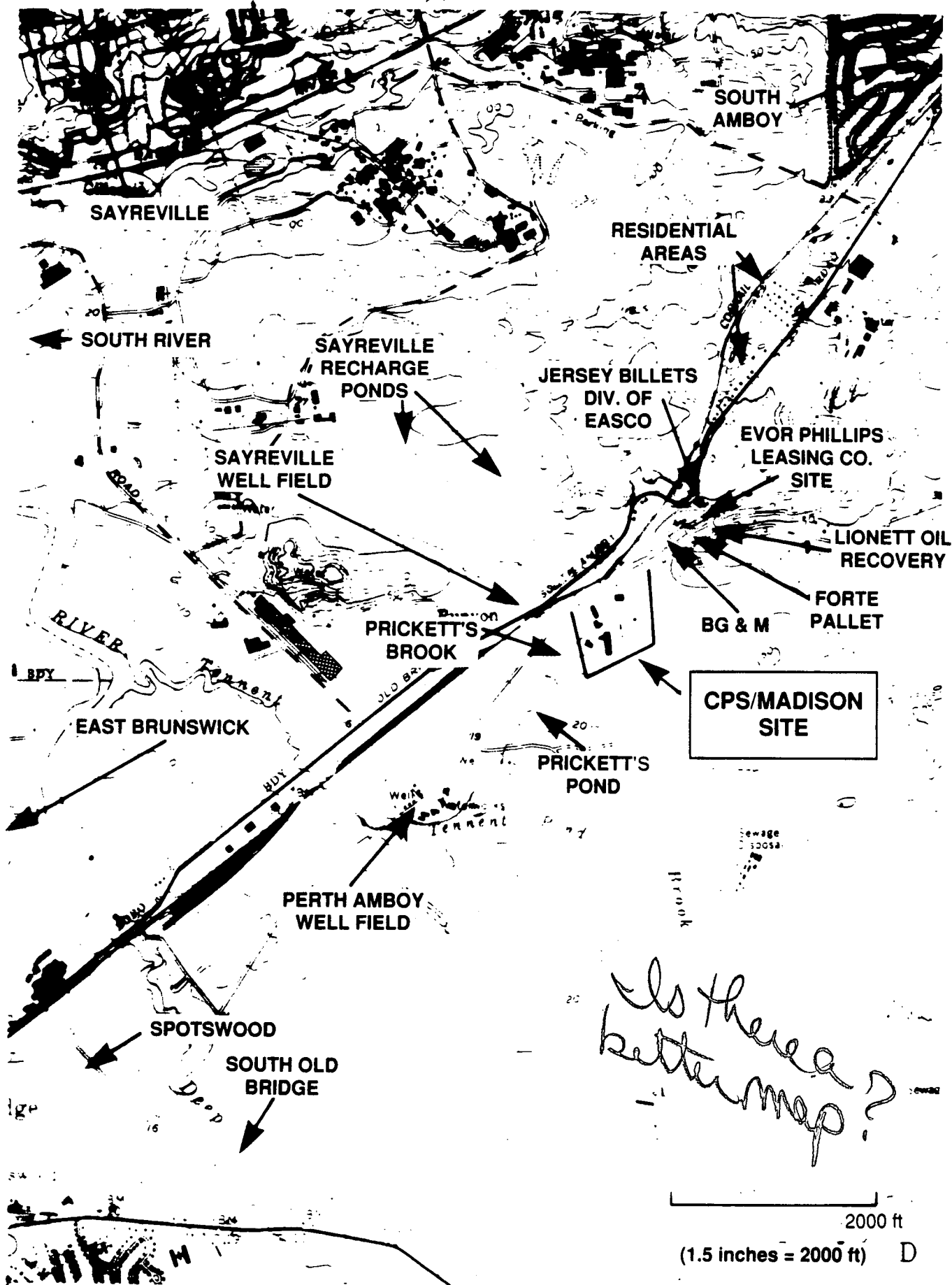


FIGURE 1-1. CPS/MADISON REGIONAL LOCATION MAP

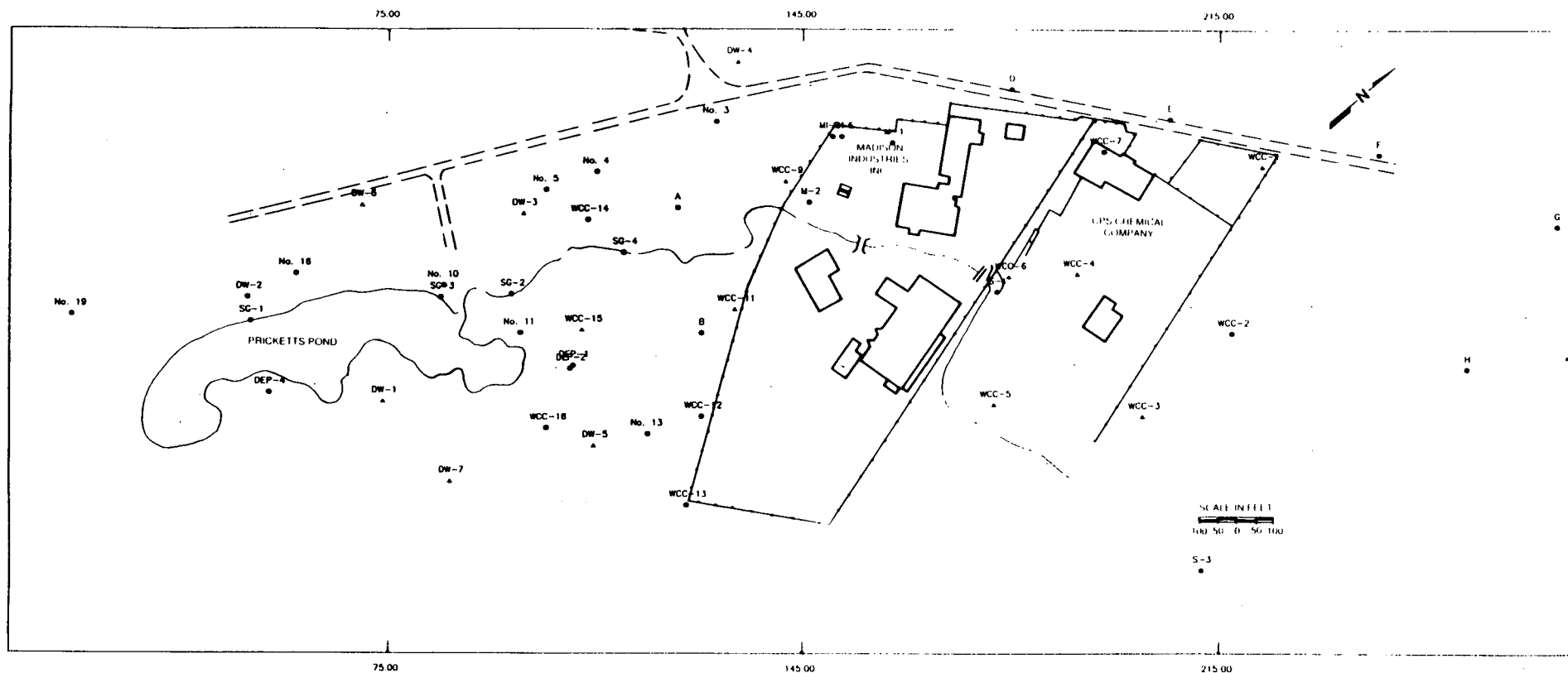


FIGURE 1-2. CPS/MADISON SITE MAP-SELECTED WELL LOCATIONS

chemicals, primarily zinc salts that are used in fertilizers, pharmaceuticals, and food additives.

1.1.2 Site History

In 1970, high levels of zinc were detected in Perth Amboy's pumping wells, located southwest of the study area (see Figure 1-1). Additional contaminants were detected with further investigation and sampling. Specifically, zinc, lead, cadmium, methylene chloride, and 1,1,2,2-tetrachloroethane were identified as the major contaminants in soil, surface water, sediments, and groundwater surrounding the CPS/Madison facility. A remedial investigation was completed in 1980 (Dames and Moore) and subsequent investigations evaluated the site characterization and the proposed remediation plan. The Superior Court of New Jersey has ordered a number of actions during the history of the site. Most recently, the court ordered the implementation of the conceptual remediation plan, proposed by Converse (1983) and Wehran (1984). An outline of the major events that have occurred during the history of investigation of the CPS/Madison site is presented in Appendix A.1. The objectives of the investigations conducted to date have been (1) to define the source, nature, and extent of contamination; and (2) to characterize the subsurface hydrogeology in order to recommend an appropriate remedial action.

A foot note at the bottom of the page explaining who these 2 firms represent would be helpful.

1.1.2.1 Past Waste Disposal Practices and Contaminant Releases

Analyses of soil, groundwater, sediment, and surface water samples have revealed significant heavy metal contamination at the CPS/Madison facilities. In 1973, the Madison Township Sewer Authority (MTSA) conducted a television inspection of the sewer line that runs through the CPS/Madison facility. The inspection revealed a break in the sewer line. Due to the lack of records

and information, the amount of contamination attributable to the sewer break is unknown. It is not clear whether actions were taken to prevent further contamination from the leak (e.g., remediation measures). MTSA did instruct Madison Industries to install a pretreatment device to reduce the highly acidic effluent discharged to the sewer line, however.

you should back this statement up w/ a reference
In a 1975 report by Ad-Tek Engineering, Madison Industries, which manufactures zinc salts and other chemical compounds, was identified as the source of the metals contamination. Accounts of early operations at the Madison facility indicated poor "house-keeping" and waste management practices as the probable cause of contaminant migration to the environment. For example, raw materials were stored on the ground in direct contact with soils. As a result, contaminants were transported by direct infiltration into the groundwater and by surface runoff to Pricketts Brook. *According to the report?*

Figure? where in relation to site.
Other potential sources of contamination discussed in the 1975 Ad-Tek report include a closed dump at the intersection of Waterworks and Perrino Roads. The dump was approximately 2 miles upgradient of the Perth Amboy well field. In addition to the dump, other minor instances of indiscriminant dumping along roads in the watershed were mentioned by Ad-Tek, although contamination from other sources was never confirmed.

In 1976, organic contaminants were detected in groundwater and other media. Methylene chloride and 1,1,2,2-tetrachloroethane were identified as the principal organic contaminants. In a 1980 report (Dames and Moore), the contaminants were attributed to the CPS Chemical Company, which produces and stores organic compounds (e.g., esters and alcohols). In addition to poor house-keeping practices, a railroad tank car unloading area, two large chemical storage *Not same. Is this what the reports say.*

tanks, and fuel oil storage tanks were identified as the most probable sources of contaminant releases.

pursuant to the
According to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) site investigation conducted in August 1982, CPS/Madison was under at least 50 criminal indictments for illegal dumping of hazardous wastes. In addition, an accidental discharge of chemicals occurred on August 1, 1979, from a ruptured disc located in a reaction vessel at the CPS facility.

The Evor Phillips Leasing Company (EPLC) Superfund site, located immediately north of the CPS/Madison site (see Figure 1-1), is a potential offsite source of contamination of the Perth Amboy well field. Alleged disposal practices at EPLC include direct discharge of bulk acids and caustic solutions to the ground; and the burial of several hundred drums (possibly gas cylinders), a box trailer filled with leaking drums, and a 5,000 gallon tank trailer. Oil spills are thought to be associated with oil recovery operations conducted at the EPLC site. Additionally, wastes associated with silver recovery operations at the EPLC site were reportedly discharged directly to the ground.

Legal and Regulatory History

After groundwater contamination was detected in the Perth Amboy pumping wells, the New Jersey Department of Environmental Protection (NJDEP) in 1971 ordered the partial shut down of Perth Amboy's Bennet Suction Line wells, which are located in a line southwest of the study area (see Figure 1-3). In 1973, the Bennett Suction Line wells were completely shutdown. After the sewer line break was discovered, the State ordered Madison Industries to cease the discharge of improperly treated

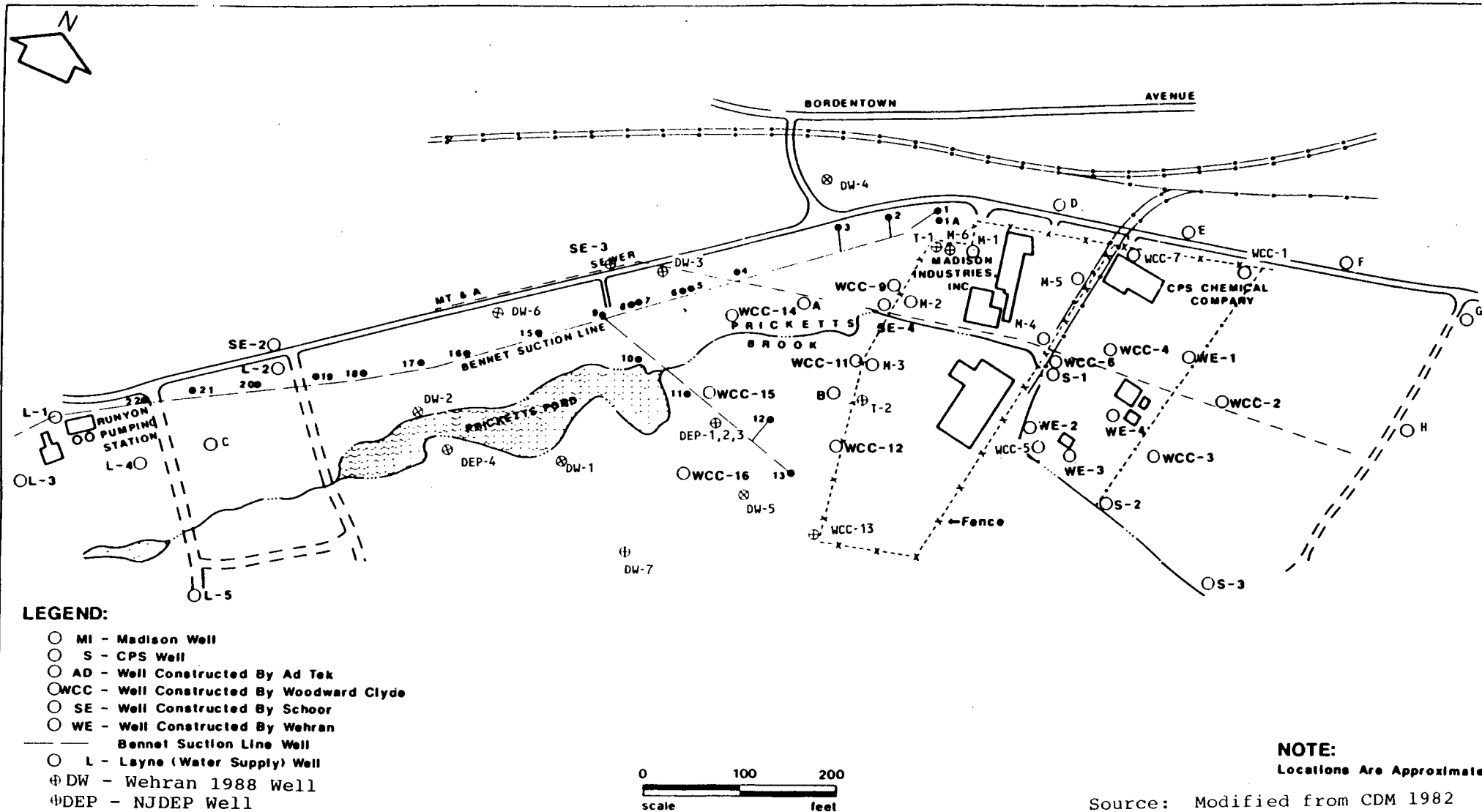


FIGURE 1-3. LOCATION OF WELLS IN THE STUDY AREA

industrial wastewater to the MTSA. A number of apparent violations by CPS/Madison Industries were cited throughout the history of site investigations. As mentioned previously, the CERCLA site investigation, completed in August 1982, documented *noted?* at least 50 criminal indictments for illegal dumping of hazardous wastes by CPS/Madison Industries.

In 1979, the New Jersey Superior Court issued an order to investigate and remediate the contamination in the vicinity of the CPS/Madison site. Since that initial action, the Court has reviewed several proposed and amended remediation plans. Appendix A.1 presents a complete summary of the legal and regulatory events that have occurred during the history of investigation of the CPS/Madison site.

The first remediation plan presented to the Court was proposed by Dames and Moore in 1980. Dames and Moores' plan involved (1) a slurry wall to isolate contaminated groundwater; (2) a groundwater recovery system (i.e., pump and treat method); (3) rerouting of Pricketts Brook; and (4) dredging of Pricketts Pond. In 1981, the Court filed an order mandating implementation of the remediation plan proposed by Dames and Moore. This order was followed by allocation of \$5.2 million to the State and the city of Perth Amboy for the cost of remediation.

In 1981, CPS/Madison filed an appeal to the Court requesting that the remediation plan be amended due to a number of inconsistencies in the interpretation of both site characteristics and the nature and extent of contamination. On behalf of CPS/Madison, Wehran and Converse Consultants presented an amended remediation plan to the Court in 1983. Further amendments to the revised remediation plan were made in subsequent years as a result of additional sampling and investigation by Wehran and Converse. A final court order was made in 1988 that directed

implementation of a remediation plan involving (1) a slurry wall in conjunction with a groundwater recovery system, as proposed by Wehran on March 28, 1984; (2) relocation of Pricketts Brook, as proposed by Converse on May 27, 1983; and (3) discharge of recovered groundwater to the MTSA.

1.2 PREVIOUS STUDY AREA INVESTIGATIONS

A list of major documents available describing previous investigations and the major conclusions made from these investigations are presented in Table 1-1. This table documents groundwater, soil, surface water, and sediment sampling events and includes the date, the organization that performed the sampling, the type and location of the sample, the tests performed, and comments.

1.2.1 Geological Investigations

Early efforts to summarize site geology relied on various geological publications (i.e., geologic and groundwater reports) that provide regional information regarding the geology of the Atlantic Coastal Plain of New Jersey. Site-specific information, such as the description of the local surface and subsurface characteristics and the vertical and lateral extent of geologic units, was not available.

Handwritten note: *See p. 4*

As described in the Wehran report (1983), seven exploratory borings were drilled at various locations onsite to determine the thickness and extent of the geologic units beneath the study area. Based on the exploratory borings, Wehran concluded that the South Amboy Fire Clay is discontinuous and therefore, could not serve as an effective layer to confine contamination to the overlying sand unit. Consequently, they suggested that the

TABLE 1-1. SUMMARY OF SAMPLING EVENTS

Date	Agency/Firm	Type of Sample	Location of Sampling	Tests Performed	Analytical Methods	Comments	Source
1971	City of Perth Amboy	GW	Bennet Suction Line (BSL) Wells	Zn	Not provided.	Tests performed and well numbers were not specified.	Ad-Tek 1975
Jan 13 1971	NJDEP (R. Barg)	SW	Puddles and riverlets on Madison grounds	Pb, Hg, Cd, Ar, Zn, Fe (total), Cu, sulfate	Not provided.	Number of samples was not specified.	Ad-Tek 1975
Jan 25 1971	NJDEP (R. Barg)	SW	Puddles and riverlets on Madison grounds	Pb, Cd, Zn, Cu, Fe, Al, Mg, Mn, chlorides	Not provided.	Number of individual samples that made up composite was not given.	Ad-Tek 1975
Mar 1971	NJDEP	SW	Puddles and riverlets on Madison grounds	Pb, Zn, Cd, Mn	Not provided.	Unclear whether these were the only tests performed.	Ad-Tek 1975
Feb 9 1973	NJDEP (DeNito)		Pretreatment holding pit during washing process after a spill near Madison Industries	Pb, Zn, Cu, Al, Mg, Mn	Not provided.	Type of sample was not specified.	Ad-Tek 1975
Feb 28 1973	NJDEP	SW	Pricketts Brook opposite Layne Well # 4	Pb, Cd, Zn, Cu, Fe, Mg, Mn, chlorides	Not provided.	o Location map of specific sampling points was not provided. o Number of sample(s) was not given.	Ad-Tek 1975
Mar 1973	Mikulka (NJDEP)	GW	"Selected well points of Perth Amboy well field"		Not provided.	No further description available.	Ad-Tek 1975

TABLE 1-1. SUMMARY OF SAMPLING EVENTS (Continued)

Date	Agency/Firm	Type of Sample	Location of Sampling	Tests Performed	Analytical Methods	Comments	Source
Mar 1973	Mikulka (NJDEP)	SW	Tennent (Runyun) Pond	Zn, Pb, Al, Cd, Fe, Cu, SO ₄ , BOD, COD, pH, SS, turbidity	Not provided.	Map from Ad-Tek describes sampling points.	Ad-Tek 1975
Apr 16 1973	NJDEP (Vernum)	SW	Pricketts Brook entering and leaving Madison	Pb, Cd, Zn, Cu, Fe, Al	Not provided.	Number of sample(s) was not given.	Ad-Tek 1975
Mar-Apr 1973	Schoor Eng.	GW	BSL and SE wells	Cd, Pb, Zn	Not provided.	Specific well numbers and complete lists of tests performed were not specified.	Ad-Tek 1975
Mar-Apr 1973	Schoor Eng.	SW	Aluminium Billets Corp. pond	Cd, Pb, Zn	Not provided.	Did not specify if other tests were performed.	Ad-Tek 1975
Apr 3-6 1973	Schoor Eng.	SOIL	4 locations at the Madison facility	Zn, Cd, Pb	Not provided.	Sampling points were not specified on location map.	Ad-Tek 1975
June 1973	NJDEP	SW	Pricketts Brook	Heavy metals	Not provided.	Did not specify the type of heavy metals.	Ad-Tek 1975
July 1973	NJDEP (Hamilton)	SW	Pricketts Brook, entering and leaving Madison	Pb, Zn, Cd, Cu, Fe	Not provided.	Number of sample(s) was not given.	Ad-Tek 1975
Sept 1973	NJDEP (Hamilton)	SW	Pricketts Brook, leaving Pricketts Pond	Pb, Zn, Cd, Cu, Fe	Not provided.	Number of sample(s) was not given.	Ad-Tek 1975
Nov 1974	Ad-Tek	SW	Pricketts Brook, at entrance to Pricketts Pond	Pb, Cd, Zn, Hg, pH	Not provided.	Number of sample(s) was not given.	Ad-Tek 1975

TABLE 1-1. SUMMARY OF SAMPLING EVENTS (Continued)

Date	Agency/Firm	Type of Sample	Location of Sampling	Tests Performed	Analytical Methods	Comments	Source
Dec 1974	Ad-Tek	SW	Pricketts Brook, at entrance to Pricketts Pond	Pb, Cd, Zn, Hg, pH	Not provided.	Number of sample(s) was not given.	Ad-Tek 1975
Jan 1975	Madison Ind. (Dr. Faust)	SW	Pricketts Brook watershed	Heavy metals	Not provided.	o Only Zn analyses were given. o Number of samples were not specified.	Ad-Tek 1975
Jan 1975	Madison Ind. (Dr. Faust)	SOIL	o Surface, near stream, above CPS o Surface of gully leading into Pricketts Pond	Zn, Pb	Not provided.		Ad-Tek 1975
Feb 1975	Ad-Tek (J.V.Hunter)	SED	Pricketts Brook watershed	Zn, Pb, Cd	Samples were digested as recommended in "Methods for Chemical Analysis of Waters" (EPA 1971). Zn was diluted as recommended in "Analytical Methods for Atomic Absorption Spectrophotometry" (Perkin Elmer 1971), and Pb and Cd were diluted as recommended in "Standard Methods for the Examination of Water and Wastewater" Amer Public Health Association, 13 ed, 1971.		Ad-Tek 1975
Feb 1975	Ad-Tek (J.V.Hunter)	other	Steel barrel at Madison property	Zn, Pb, Cd	Not provided.		Ad-Tek 1975

TABLE 1-1. SUMMARY OF SAMPLING EVENTS (Continued)

Date	Agency/Firm	Type of Sample	Location of Sampling	Tests Performed	Analytical Methods	Comments	Source
Feb 1975	Ad-Tek (J.V.Hunter)	SW	Pricketts Pond, entrance and pond	Zn, Pb	Samples were digested as recommended in "Methods for Chemical Analysis of Waters" (EPA 1971) and analyzed using a Perkin Elmer 403 Atomic Absorption unit as recommended in "Analytical Methods for Atomic Absorption Spectrophotometry" (Perkin Elmer 1971).		Ad-Tek 1975
1975	Ad-Tek	GW	A,B,D,E,F,G,H (AD) wells and BSL No. 1,3,4,11,13 wells		Samples were digested as recommended in "Methods for Chemical Analysis of Waters" (EPA 1971) and analyzed using a Perkin Elmer 403 Atomic Absorption unit as recommended in "Analytical Methods for Atomic Absorption Spectrophotometry" (Perkin Elmer 1971).	No further information available. (Ad-Tek p. 27,45).	Ad-Tek 1975
1976-8	NJDEP	GW	AD,S,M,BSL wells	Zn, Pb, MeCl, 1,1,2,2-tetra-chloroethane	Not provided.		Dames & Moore 1980
Oct 5 1979	Dames&Moore	SW	Pricketts Brook	Zn, Pb, MeCl, 1,1,2,2-tetra-cholorethane	Not provided.		Dames & Moore 1980

TABLE 1-1. SUMMARY OF SAMPLING EVENTS (Continued)

Date	Agency/Firm	Type of Sample	Location of Sampling	Tests Performed	Analytical Methods	Comments	Source
Oct 8 1979	Dames&Moore	GW	Wells A,B,D,E,S-1 M-1,M-2,M-3	Zn, Pb, MeCl, 1,1,2,2-tetra- chlorethane	Not provided.		Dames & Moore 1980
Jan-Feb 1980	Dames&Moore	SED	o Near south bank, 150 ft upstream of Pricketts Brook from out of the pond o Middle part of pond, 250 ft from #1 o Pricketts Pond, near entrance of the brook	Pb, Zn, Cd	Not provided.	o Sample identification numbers of laboratory reports are unclear. o Missing Figure 2 from reference that indicates sample locations.	Dames & Moore 1980
Jan-Feb 1980	Dames&Moore	SOIL	Wells A,D,F,S-1, S-2,S-3,M-1,M-2 M-3,M-4,M-5,SE-1 SE-2,SE-3,SE-4, & 8 surficial points	Pb,Zn,Cd,MeCl 1,1,2,2-tetra- chlorethane	Not provided.		Dames & Moore 1980
1982	NJDEP	GW	WCC wells	Pb, Cd, Zn, Cu, 30 VOCs	Not provided.		Wehran 1983
Mar 1982	PAS/NJDEP	GW	WCC, BSL, M, and S wells	Pb, Zn, Cd, Cu	Not provided.	No summary/text provided with the laboratory results.	PAS 1982
1983	PAS	GW		Pb, Zn, Cd, Cu	Not provided.	Well locations were not provided.	PAS 1982

TABLE 1-1. SUMMARY OF SAMPLING EVENTS (Continued)

Date	Agency/Firm	Type of Sample	Location of Sampling	Tests Performed	Analytical Methods	Comments	Source
May 1983	Converse Consultants	GW	M,BSL,WCC, and PA wells	Zn, Pb, Cu, Cd chlorides,sulfates	"Standard Methods for Examination of Wastewater" 14 ed. and "Methods for Chemical Analysis of Water and Wastes", EPA.		Converse 1983
May 1983	Converse Consultants	SW		Zn, Pb, Cu, Cd chlorides,sulfates	"Standard Methods for Examination of Wastewater" 14 ed. and "Methods for Chemical Analysis of Water and Wastes", EPA.	Sampling locations not specified.	Converse 1983
May 1983	Converse Consultants	SOIL	WCC,T-1,BSL wells	Zn, Pb, Cu, Cd chlorides,sulfates	Extraction potential analysis as directed in the Federal Register, Vol. 45, No. 98, May 19, 1980.		Converse 1983
May 1983	Converse Consultants	SED		Zn, Pb, Cu, Cd	"Standard Methods for Examination of Wastewater" 14 ed. and "Methods for Chemical Analysis of Water and Wastes", EPA.	Sampling locations not specified.	Converse 1983
Apr 1984	Converse Consultants	SED	Pricketts Pond	Pb, Zn, Cd, Cu	Direct aspiration atomic absorption spectroscopy (Model IL-751).		Converse 1983

TABLE 1-1. SUMMARY OF SAMPLING EVENTS (Continued)

Date	Agency/Firm	Type of Sample	Location of Sampling	Tests Performed	Analytical Methods	Comments	Source
Apr 1984	Wehran Eng.	SED	Pricketts Pond	33 VOCs	EPA Method 8240 (GC/MS method for volatile organics).		Wehran 1984
June 1984	NJDEP	SW	Pricketts Brook o Downstream of Madison's fence, o As discharging to the pond, and o Behind water plant - east side	Pb, Zn, Cd, Cu, VOCs	EPA-600/4-79-020, revised Mar 1983 for water and wastewater, EPA SDW-846 2nd ed., July 1982 for soil, sediment, and sludge. EPA 600/4-82-057, EMSL, Cincinnati, OH, 45268 July 82, PTS SOP 7.1.2-3.	No summary/text was provided.	NJDEP 1984
May 1985	NJDEP	GW	WCC-15S;BSL No.3, 10,12;A,B;Sayre-ville-Production Well-A	VOCs, Pb,Zn,Cd,Cu	Not provided.	No summary/text was provided.	NJDEP 1985
Mar 1987	Wehran Eng./ YWC	GW	PA, WCC, DEP, M wells	30 VOCs	Some VOCs by purge and trap GC/MS (by York Lab Div of YWC), others by NJDEP not provided; some metals by "Standard Methods for the Examination of Water and Waste" and EPA "Methods for Chemical Analysis of Water Wastes" (by L/Baklabs 1984); others methods not provided by Nonco Lab Inc and NJDEP.	No summary/text was submitted with the laboratory results. Could not determine name of lab: "Baklabs" or "Laklabs".	Wehran/ YWC 1987
Nov 1988	Wehran Eng.	GW	DW,WCC,DEP,M wells	Zn,Pb,Cu,Cd, 29 VOCs	Not provided.		Wehran 1989

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June 30, 1989

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proposed slurry wall extend to a deeper, continuous clay layer (i.e., the Woodbridge Clay).

Working for the State?

In their 1984 Design Review Report, CH2M Hill assumed, for the purpose of their proposed remedial action plan, that the South Amboy Fire Clay was continuous and non-leaking (i.e., groundwater does not flow through the unit). CH2M Hill's assumption was based on the examination and interpretation of logs from borings drilled along the proposed slurry wall location. CH2M Hill concluded, however, that additional subsurface information was needed in the northern and southwestern portion of the proposed slurry wall location to verify the presence of the South Amboy Fire Clay.

In 1986, Wehran further investigated the uppermost clay unit to more accurately determine if the clay's continuity, thickness, and permeability were adequate for use as a basal confining layer for the proposed slurry wall. Geologic logs for more than 70 test borings, monitoring wells, and water supply wells were compiled and reviewed. In addition, borehole geophysical logs (gamma logs) were examined for 23 borings drilled by the NJDEP. Wehran concluded that the clay unit, thought to be South Amboy Fire Clay, could not be correlated on the western portion of the site with a similar unit on the eastern portion of the site.

Independent.

Dr. Richard Olsson of Rutgers University reviewed the geologic interpretations presented by Wehran (1986) and CH2M Hill (1984). Palynological age dating of selected samples from boreholes located on the site was performed to precisely correlate geological units described on borehole logs. Dr. Olsson concluded that the South Amboy Fire Clay, the uppermost clay unit, is too thin and discontinuous beneath the northern portion of the site to serve as a basal confining layer for a slurry wall. In addition, he concluded that the deeper

Woodbridge Clay is easily identifiable and widespread throughout the site area.

1.2.2 Surface-Water and Sediment Investigations

Surface-water and sediment investigations have been conducted to identify (1) the source of contamination, (2) the extent and nature of contamination in these media, and (3) the surface-water and groundwater interactions (e.g, whether surface-water contamination is due to surface runoff and/or discharge of contaminated groundwater).

In order to identify the origin of contamination, between 1971 and 1973, NJDEP sampled and tested surface-water and sediment samples upgradient and downgradient of the CPS/Madison site and random water puddles and riverlets on the Madison property. Pricketts Brook and Pricketts Pond were sampled in 1973, 1974, and 1975 (see Table 1-1). The Ad-Tek's report (1975) reviews these sampling results and concludes that contaminants in the sediment and surface water is caused by stormwater runoff from the Madison Industries. Ad-Tek showed that the concentration of contaminants in surface water and sediments varied depending upon the amount of time that had elapsed since the last rainfall event, suggesting that the greater the amount of elapsed time, the greater the accumulation of contaminants on the land surface and thus, the greater the concentration of contaminants in the stormwater runoff. Ad-Tek recommended that contaminated sediment be dredged and disposed of offsite.

Dames and Moore (1980) collected a composite surface-water sample from Pricketts Brook in October 1979 and four sediment samples from Pricketts Pond in January and February of 1980. They did not present any conclusions from the review of these analytical results other than to note the presence of metals.

believe

In 1984, both Converse and Wehran drilled 15 borings in Pricketts Pond and concluded that the upper 1 to 2 feet of sediment contained residual levels of low-grade contamination. Converse and Wehran did not think that the dredging and offsite disposal of the sediment in Pricketts Pond or the sediment along Pricketts Brook was warranted.

Wehran (1984) proposed two likely mechanisms responsible for introducing contaminants into surface water and sediments of Pricketts Pond. These mechanisms are described as (1) the discharge of contaminated surface water due to surface runoff from Pricketts Brook to Pricketts Pond, and/or (2) the discharge of contaminated groundwater into the Pond from the underlying Aquifer.

Based on monitoring well and staff gauge data (Wehran 1989), Wehran concluded that groundwater discharges into Pricketts Pond from the north, and that the Pond discharges to the groundwater to its south. As discussed in Geraghty and Miller (1987), however, well clusters (DEP 1 through 3) adjacent to the Pond (DEP 1 through 3) indicate a downward hydraulic head in 1987 and therefore, Pricketts Pond may not serve as a discharge point for all groundwater upgradient of the Pond.

Surface-water and sediment sample locations for all samples collected during the investigations of the CPS/Madison site and corresponding analytical results (when provided), are presented in Appendix A.2.

What is your conclusion?

1.2.3 Soil Investigations

Surficial and subsurface soils in the study area have been sampled and analyzed during five sampling events (Wehran and Converse 1983, Dames and Moore 1980, Ad-Tek 1975, Schoor 1973,

and NJDEP pre-1975). All sample analyses indicate metal contamination of soils. Selected soil samples collected during Wehran's 1983 field investigation were analyzed for volatile organic priority pollutants or organic carbon, and at least one sample out of the five contained relatively high (total volatile priority pollutants = 158 ppb) levels of organic contaminants. Available information on soil sample locations and analytical results for soil samples are presented in Appendix A.3.

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A description of the surficial soils in the vicinity of the CPS/Madison site is provided in CH2M Hill (1984). Additional information is available in the U.S. Department of Agriculture Interim Soil Survey Report of Middlesex County, New Jersey (1987).

The CPS/Madison site was not paved between 1967 and 1973, and a subsurface investigation was not conducted prior to paving the site. Earlier reports, particularly Ad-Tek 1975, state that soils beneath the pavement were expected to be highly contaminated, "It is suspected that a lens of heavily polluted soil exists below the Food Additives property (Madison Industries) from direct infiltration of heavy metals during the period of years before the plant operations area was paved" (Ad-Tek 1975). In addition, Harry L. Motto (Ad-Tek Engineering) reported on March 18, 1975, "From visual inspection from outside the Food Additives property, it appears that there is contamination by direct runoff to Pricketts Brook and to soil surrounding the blacktop (surface). Previous to the blacktopping, contamination would have infiltrated directly into the soil surrounding the plant."

1.2.4 Groundwater Investigations

Groundwater has been monitored in the study area ever since high levels of zinc were detected in routine analyses of water samples collected from Perth Amboy's well field in 1970. Numerous groundwater investigations have been conducted to determine (1) the nature and extent of groundwater contamination, (2) hydrologic properties of the subsurface units, and (3) saltwater intrusion.

1.2.4.1 Nature and Extent of Groundwater Contamination

In 1974, Ad-Tek monitored the existing suction wells (Numbers 1,2,3,4,5,10,11,16, and 18) and seven observation wells (A,B,D,E,F,G, and H [Ad-Tek 1975]). Groundwater samples were analyzed for cadmium, lead, and zinc. Analytical results for samples collected from monitoring wells that were installed and sampled between 1976 and 1979 are summarized in Dames and Moore (1980). At that time, the list of monitoring wells included NJDEP wells S-1 through S-3 and Madison Industries wells M-1 through M-5, in addition to the previously monitored wells. Dames and Moore (1980) selected five major constituents of concern (cadmium, lead, zinc, methylene chloride, and 1,1,2,2-tetrachloroethane) based on organic (volatile priority pollutants) and inorganic analyses performed on samples collected during these sampling events. Dames and Moore did not provide a detailed explanation as to why these five constituents were chosen as indicator chemicals.

quote Wehran installed 28 monitoring wells (WCC-1 through WCC-7, WCC-9, WCC-11 through WCC-16), some in clusters, in 1981. In 1983, Converse and Wehran reviewed NJDEP groundwater quality data collected in 1982 and data they collected themselves in 1983. Converse and Wehran used total volatile organic compounds (TVOC),

copper, cadmium, lead, and zinc as indicators of the extent of contamination. Wehran installed an additional 13 monitoring wells in 1988 (DW-1 through DW-7). Samples were collected from 17 existing monitoring wells in addition to the newly installed wells. Samples were analyzed for cadmium, copper, lead, zinc, and TVOC.

In 1980, Dames and Moore delineated concentration zones of cadmium, lead, zinc, methylene chloride, and 1,1,2,2-tetrachloroethane in groundwater. The upper 50 feet of the Old Bridge Aquifer and, possibly, the entire thickness within the areal extent of the plume were described as heavily contaminated. Wehran (1983) presented a vertical cross-section of TVOC, indicating that the highest concentrations of contaminants existed at shallow depths at the CPS/Madison boundary; at moderate depths southwest of Madison; and then again at shallow depths near Pricketts Pond. Wehran plotted TVOC concentrations detected at shallow depths in a plan view to show the lateral extent of contamination. Wehran's map depicted the CPS/Madison site as a contaminant source and showed that the plume corresponded with the general southwesterly groundwater flow direction. Zinc concentrations, detected at moderate depths, were also presented in the plan view by Wehran (1983). The zinc isoconcentration contours did not extend to the northern portion of the study area, however.

Additional isoconcentration maps of zinc and TVOC based on the 1988 data were presented by Wehran (1989). The most elevated levels of zinc were detected directly beneath the Madison property. Elevated TVOC levels were found immediately east and upgradient of Pricketts Pond. Wehran noted large concentration differences in zinc and TVOC between shallow (0 to 30 feet below land surface [BLS]) and deep (>30 feet BLS) monitoring wells. Higher concentrations were found in the shallow wells.

W. J. Wehran
1-22

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Refer to Appendix A.4 for the analytical results of zinc, lead, cadmium, methylene chloride, and 1,1,2,2-tetrachloroethane for all groundwater samples. Appendix A. provides a table of additional organic constituent concentrations detected in groundwater samples.

1.2.4.2 Hydrologic Properties of the Subsurface Units

Information on hydrologic properties of subsurface units have been obtained through pump tests and laboratory measurements, such as porosity and permeability tests (see Table 1-2). Based on pump test data and porosity measurements reported in Barksdale (1943), Dames and Moore (1980) concluded that the Old Bridge Aquifer is characterized by high to very high permeability and transmissivity.

In an effort to simulate remedial alternatives, Wehran (1983) devised a computer model that required aquifer permeability and porosity as input parameters. Wehran choose the same values for these parameters as those reported in Dames and Moore (1980). Wehran (1986) also reported a hydraulic conductivity of the Woodbridge Clay unit from Farlekas (1979). CH2M Hill (1984) calculated transmissivity and storativity of the Old Bridge Aquifer using Wehran pump test data (date not specified). *Any conclusion*

Water levels have been measured in wells within the study area in March 1979, March 1982, March 1983, and November 1988 (see Table 1-3). These water levels and water-level contour maps are presented in Dames and Moore (1980), Wehran (1983), and Wehran (1989), respectively. All of the data indicate a southwesterly groundwater flow direction.

TABLE 1-2. HYDROLOGIC PROPERTIES

Parameter Value	Geologic Unit	Location	Method	Date	Source of Information	Comment
Conductivity (K)						
K=4.73 E-2 - 7.056 E-2 cm/sec	Old Bridge	NA	Pump Test Data	1943	D&M 1980	Measurement taken from Barkdale (1943).
K=4.73 E-2 - 7.33 E-2 cm/sec	Old Bridge	NA	Laboratory Permeability	1962	D&M 1980	Sample location was not specified.
K=3.00 E-9 cm/sec	Woodbridge Clay	NA	NA	1979	Wehran 1983	Measurement was taken from Farlekas (1979).
K=1.0 E-7 cm/sec	Woodbridge Clay	NA	NA	NA	Wehran 1983	Estimate of upper limit of permeability (conservative estimate) presented by Wehran.
K=2.717 E-7 cm/sec	Woodbridge Clay	B-1 (S-28)	Laboratory Permeability	1986	Wehran 1986	
K=2.5814 E-7 cm/sec	Woodbridge Clay	B-2 (S-15)	Laboratory Permeability	1986	Wehran 1986	
K=7.9 E-8 cm/sec	Woodbridge Clay	B-3 (S-12)	Laboratory Permeability	1986	Wehran 1986	
Transmissivity (T)						
T=3.07-6.39 cm/sec	Old Bridge	NA	Laboratory Permeability	1962	D&M 1980	Sample location was not specified.
T=3.66 cm/sec	Old Bridge	Pumping Well T-1	Pump Test Data (Wehran)	NA	CH2M Hill 1984	Average of semi-log and log-log plot analysis.

TABLE 1-2. HYDROLOGIC PROPERTIES
(continued)

Parameter Value	Geologic Unit	Location	Method	Date	Source of Information	Comment
Storativity (S) S=0.039	Old Bridge	Pumping Well T-1	Pump Test Data (Wehran)	NA	CH2M Hill 1984	Average of semi-log and log-log plot analysis.
Porosity (n) n=0.35-0.42	Old Bridge	NA	NA	1943	D&M 1980	Measurement was taken from Barksdale (1943).

NA=Information is not available in document.

BLS=Below Land Surface.

TABLE 1-3. WATER LEVEL MEASUREMENTS

Well	Water Level Elevations (year)				Total Well Depth (feet)	Top of Casing	Source
	3/79	3/82	3/83	11/88			
A	19.21				51.5	22.86	D&M
B	18.69				52.0	24.99	D&M
D	23.96				52.0	29.16	D&M
E	23.96				40.0	29.08	D&M
M-1		19.68				23.79	WE '83
M-2	20.85			14.60		22.75/23.68	D&M/WE'89
M-3	19.47					22.77	D&M
M-6						48.70	WE '89
S-1	20.97				30.0	23.32	D&M
DEP-1				8.68		24.66	WE '89
DEP-2				13.80		24.38	WE '89
DEP-4				11.21		19.79	WE '89
WCC-1M		22.01	20.06	18.25	/55.10	27.31/27.88	WE '83/'89
WCC-1D		21.94		17.76	/98.90	26.79/27.77	WE '83/'89
WCC-2M		21.51	20.05	16.76	/57.21	26.34/28.20	WE '83/'89
WCC-3S		21.33	19.51			27.63	WE '83
WCC-3M				16.90	/50.76	28.39	WE '89
WCC-3D		21.36	19.74	17.63	/85.05	29.11/29.48	WE '83/'89
WCC-4S		20.74				24.25	WE '83
WCC-4D		20.73	19.20			24.57	WE '83
WCC-5S		19.99	18.11			26.96	WE '83

TABLE 1-3. WATER LEVEL MEASUREMENTS
(continued)

Well	Water Level Elevations (year)				Total Well Depth (feet)	Top of Casing	Source
	3/79	3/82	3/83	11/88			
WCC-6D		20.15	18.56			25.95	WE '83
WCC-6S		20.23		*16.62	/37.70	26.98	WE '83/'89
WCC-6S		20.19	18.46			26.35	WE '83
WCC-6M		20.23	18.32	16.55	/55.56	26.15	WE '83/'89
WCC-7M		20.87	18.42			26.36	WE '83
WCC-9S		18.69				24.34	WE '83
WCC-9M		19.30				23.95	WE '83
WCC-11S		18.04		14.83	/20.06	22.89	WE '83/'89
WCC-11M		17.91		14.89	/51.88	23.25	WE '83/'89
WCC-11D		18.06				23.21	WE '83
WCC-12M		17.89		14.56	/56.50	22.83	WE '83/'89
WCC-13M				13.60	/55.88	21.17	WE '89
WCC-14S		16.06				20.39	WE '83
WCC-15S		15.00				22.02	WE '83
WCC-15M		15.36				21.94	WE '83
WCC-16S		15.35		12.55	/20.04	23.31	WE '83/'89
WE-1			19.94			27.72	WE '83
WE-2			16.14			26.93	WE '83
WE-3			20.86			29.01	WE '83
WE-4			19.05			26.17	WE '83
DW-1S				11.46	26.15	20.68	WE '89
DW-1D				11.24	56.35	20.68	WE '89

TABLE 1-3. WATER LEVEL MEASUREMENTS
(continued)

Well	Water Level Elevations (year)				Total Well Depth (feet)	Top of Casing	Source
	3/79	3/82	3/83	11/88			
DW-2S				11.83	26.80	22.20	WE '89
DW-3S				14.49	26.29	23.97	WE '89
DW-3D				14.50	56.48	24.36	WE '89
DW-4S				15.92	27.00	27.51	WE '89
DW-4D				15.88	56.27	27.71	WE '89
DW-5S				13.35	25.48	22.79	WE '89
DW-5D				13.34	52.26	22.76	WE '89
DW-6S				13.20	26.78	21.53	WE '89
DW-6D				12.97	57.64	21.33	WE '89
DW-7S				11.22	26.17	22.91	WE '89
DW-7D				11.07	53.54	23.42	WE '89

* The 1988 data specified one WCC-6S well; therefore, it is not known to which WCC-6S well the value corresponds.
/ denotes values for 2 different years.

1.2.4.3 Saltwater Intrusion

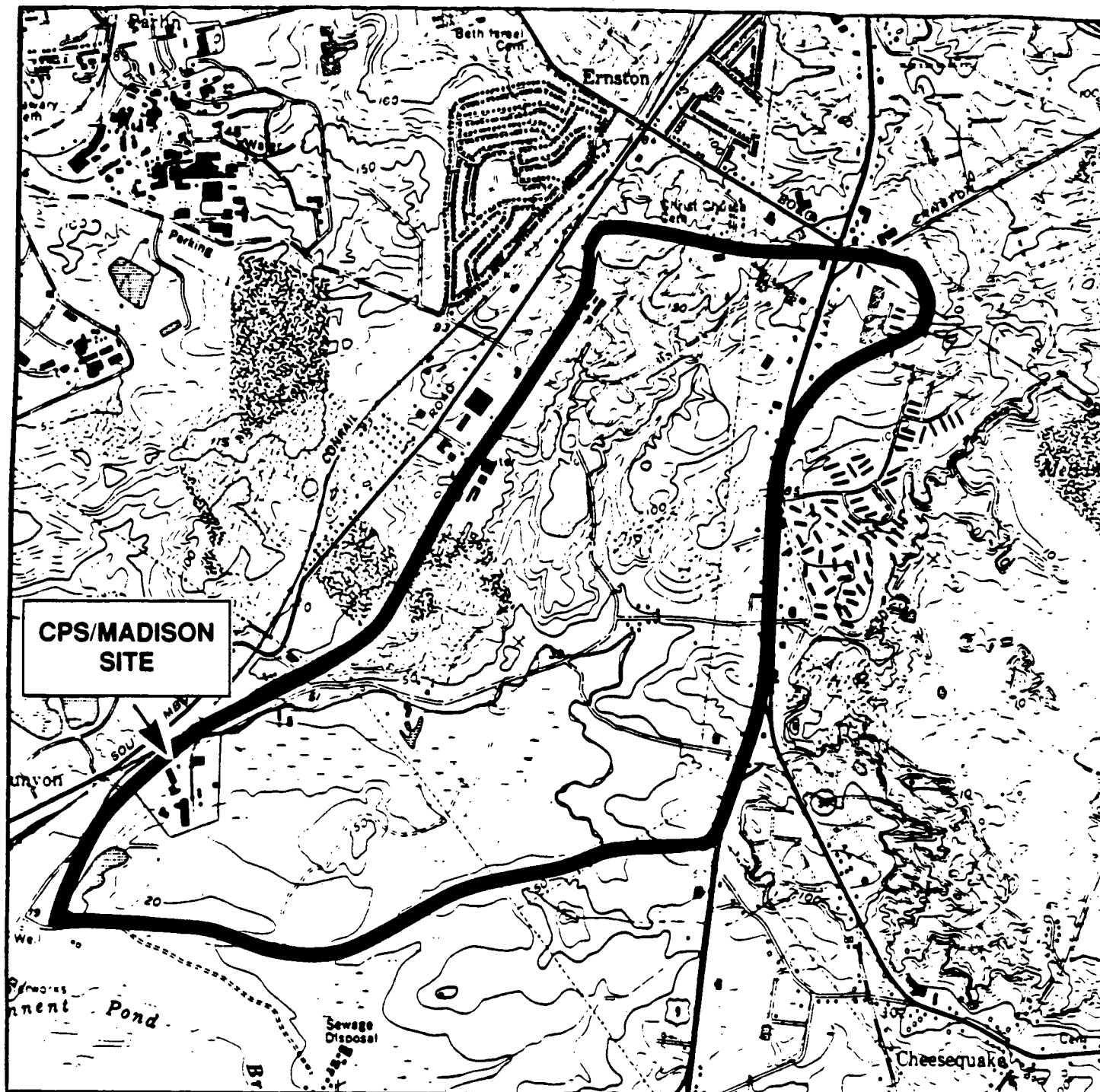
Since the 1920s, numerous studies of existing or potential saltwater intrusion in the New Jersey Coastal Plain have been conducted. The U.S. Geological Survey (USGS) maintains a saltwater-monitoring network in New Jersey to document and evaluate the movement of saline water into freshwater aquifers that serve as water supplies. In 1937, a paper by Barksdale (1937) discussed the potential for saltwater intrusion in the Farrington Aquifer in Sayreville, Middlesex County. In 1943, Barksdale and others concluded that saltwater intrusion was evident in the Farrington Aquifer in several areas along the Raritan River between South River and the Raritan Bay. Appel (1962) investigated the extent of saltwater intrusion in both the Farrington and Old Bridge Aquifers in Middlesex County. Several reports have indicated that overpumpage of the Old Bridge Aquifer could induce saltwater intrusion into the Aquifer (Barksdale et. al 1943, Appel 1962, and Hasan et. al 1969).

The most recent USGS investigation of saltwater intrusion in the Raritan Bay/Middlesex County area is near completion. A final report is in draft form but is currently not available to the public. The trends in saltwater contamination of potable aquifers are discussed in greater detail in Subsection *for incorporation into this document* ?

1.3 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

1.3.1 Surface-Water Hydrology

The CPS/Madison site is located in the Pricketts Brook watershed, as shown in Figure 1-4. The watershed area is approximately 1.8 square miles. Approximately 25 percent of the watershed is urbanized, with about 90 percent of the urbanized area in the northern portion of the watershed. The length of the watershed is approximately 14,000 feet. Elevations range from



LEGEND:

Source: CH2M Hill 1984

Watershed Boundary



SCALE
1 : 24,000

0 2000 Feet

FIGURE 1-4. PRICKETTS POND WATERSHED AREA

about 500 to 20 feet relative to mean sea level (MSL). The estimated long-term average daily flow from the Pricketts Brook watershed is 1.4 million gallons per day (gpd) (Ad-Tek 1979). The average annual precipitation rate is 44 inches. Table 1-4 provides monthly precipitation averages from the two closest weather stations (Plainfield and Freehold) for the period between 1951 and 1980. Flood potential and water-surface elevations are available through the New Jersey Bureau of Floodplain Management.

Local surface-water drainage directions are generally to the southwest (see Figure 1-5). Surface water flows across the study area from Pricketts Brook to Pricketts Pond located south of the site, which drains into Tennent Brook. Tennent Brook flows into the South River, a tributary of the Raritan River, which flows into the Raritan Bay.

Pricketts Brook originates in a marshy area about 1,000 feet above the northeast border of the CPS fence and flows through the CPS/Madison property (see Figure 1-5). From the CPS/Madison property to the top of Pricketts pond (about 700 feet), the Brook is classified as an eroding stream. Very little sediment settles out and accumulates along this portion of the Brook. Most of the suspended material is transported and deposited in Pricketts Pond.

The location of Pricketts Pond is shown in Figure 1-5. Pricketts Pond covers an area of approximately 4.5 acres. Pricketts Pond was constructed in 1973 to supplement aquifer recharge to the Bennet Suction Line Wells. The pond contains contaminated surface water and sediments.

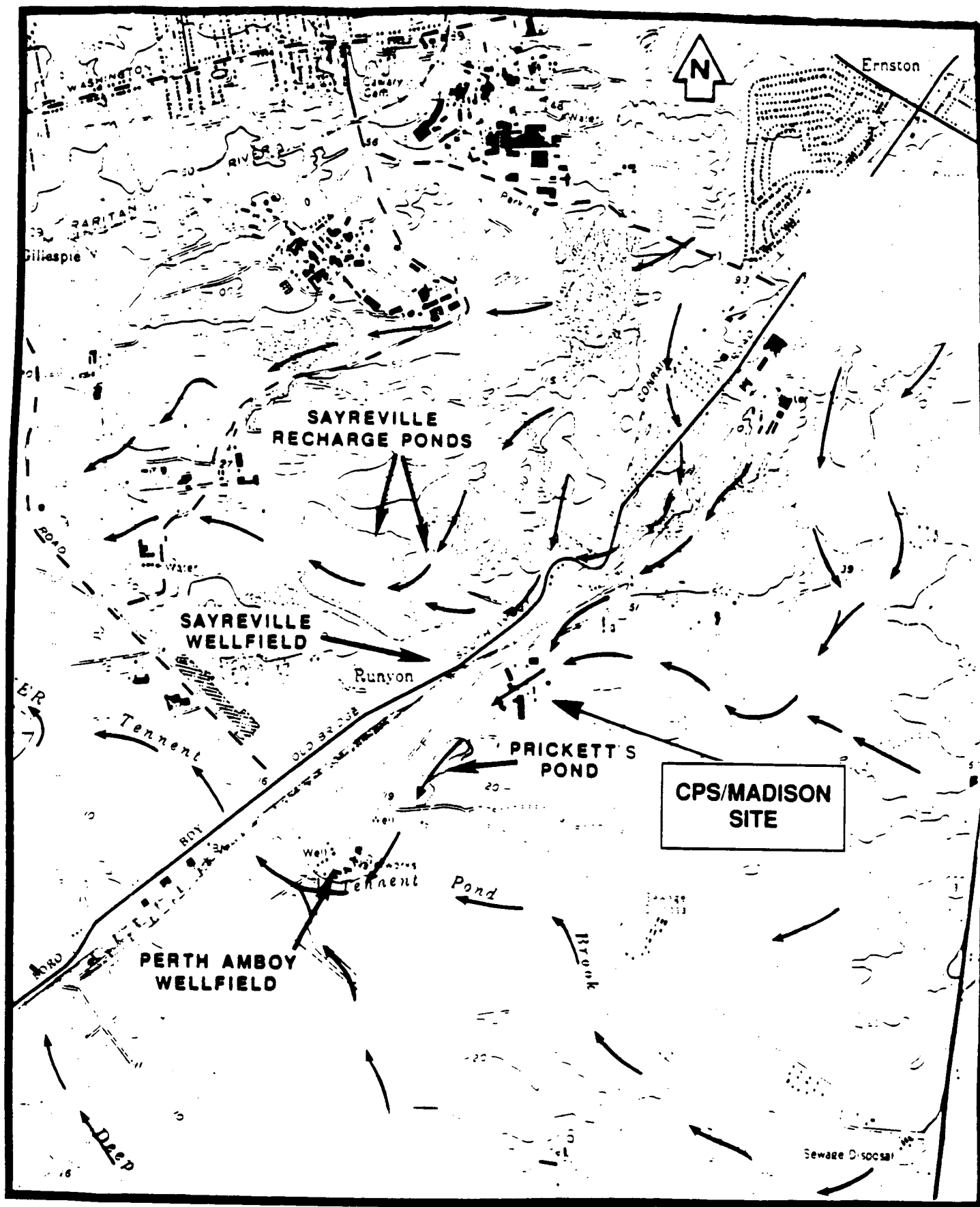
The South River is affected by tides to a distance of 7.5 miles upstream. Water quality of the South River is marginal with elevated levels of fecal coliforms and nutrients. Both

TABLE 1-4. CLIMATOLOGICAL DATA--
FREEHOLD AND PLAINFIELD, NEW JERSEY*

Month	Freehold		Plainfield	
	Mean Temperature	Mean Precipitation	Mean Temperature	Mean Precipitation
January	30.5	3.55	30.1	3.55
February	32.0	3.28	32.2	3.30
March	40.1	4.44	40.6	4.56
April	50.8	3.66	51.4	3.98
May	60.6	3.75	61.1	4.11
June	69.5	3.47	69.9	3.42
July	74.2	4.04	74.8	4.76
August	72.9	4.64	73.5	5.37
September	66.2	3.67	66.5	4.09
October	55.4	3.52	55.4	3.66
November	45.4	3.96	44.7	3.91
December	34.6	3.91	34.1	4.05

* From 1951-1980 normals.

(TRC 1987)



Source: TRC 1987

FIGURE 1-5. REGIONAL SURFACE WATER DRAINAGE PATTERNS

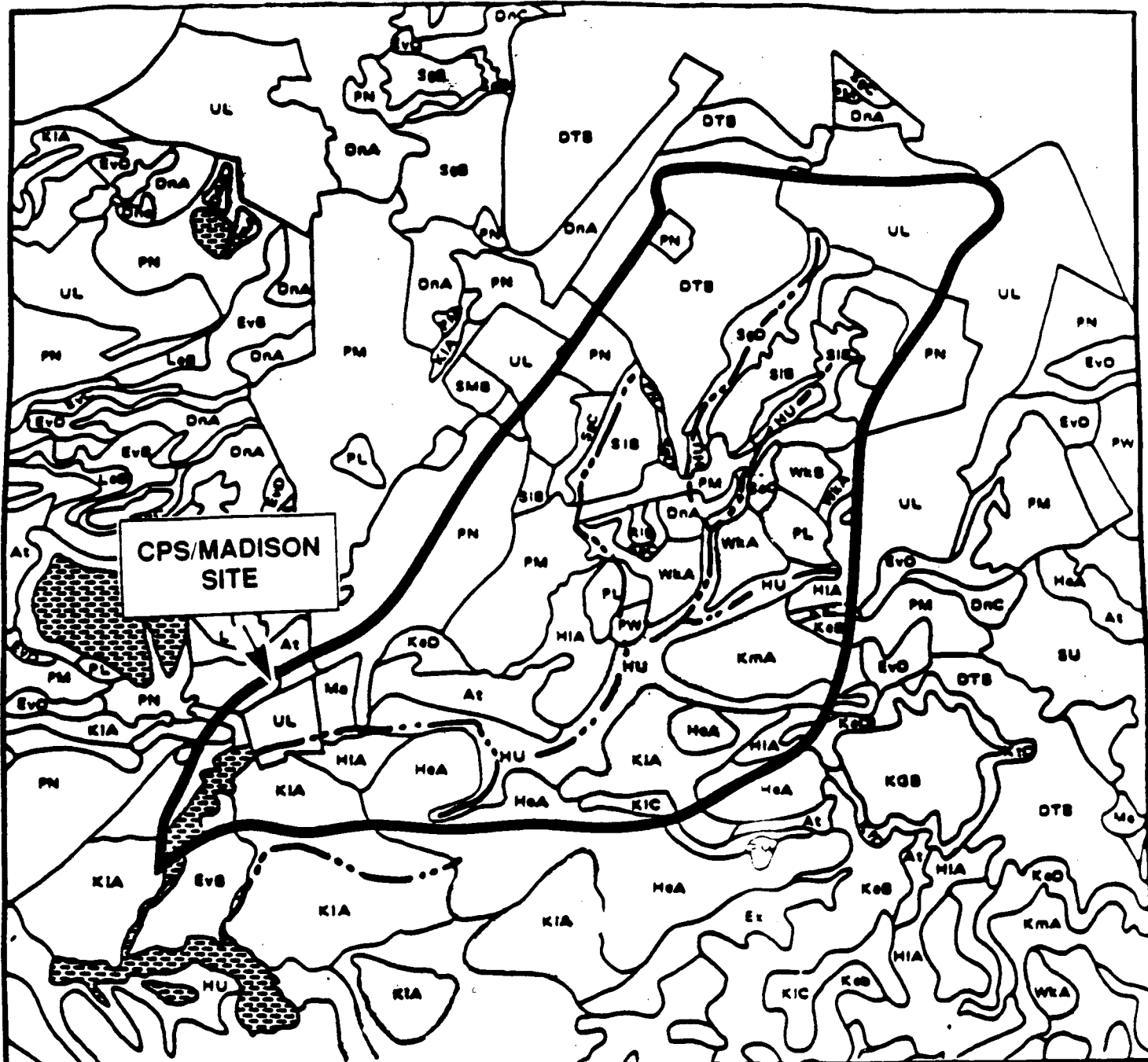
nonpoint sources (e.g., agricultural and suburban runoff) and direct discharge of contaminants have adversely influenced the water quality.

Both Pricketts Brook and Pricketts Pond have a baseflow from groundwater flowing from the northeast. Converse and Wehran (1983) suggested that the majority of the contaminants observed in the sediment can be attributed to discharge of contaminated groundwater. It is also likely, however, that surface water and sediments are contaminated from surface runoff.

1.3.2 Soils




The Pricketts Pond watershed has been divided arbitrarily into two zones--the upgradient zone and the downgradient zone. The CPS/Madison site is located in the downgradient zone, which also includes the wetland extending to the east of CPS/Madison and the area immediately downgradient of CPS/Madison to the southern tip of Pricketts Pond. The downgradient zone of the watershed encompasses about 0.6 square miles. A soil map of Pricketts Pond watershed is presented in Figure 1-6.

The watershed's downgradient zone is nearly level to gently sloping. Soils on the slopes and ridge tops are predominantly loamy sands (i.e., Klej and Hammonton). The seasonal high water table is between 1.5 and 4 feet below the ground surface in these areas. The Evesboro Sand occurs along the eastern border of Pricketts Pond. The water table in these sands has a seasonal high of 5 feet below the ground surface. Soils in the low-lying areas of the downgradient zone are subject to flooding year round. They typically have organic surface soil horizon with sandy subsoils.



Source: CH2M Hill 1984

LEGEND

-  Watershed Boundary
 Map Unit Boundary
 Map Unit Symbol
 (Refer to Index to Mapping Units)

- | | |
|-----|--|
| AT | Atsion sand |
| Ma | Manahawkin muck |
| HIA | Hammonton loamy sand,
clayey substratum,
0 to 3 percent slopes |
| KIA | Klej loamy sand,
0 to 3 percent slopes |
| UL | Urban Land |

(Refer to Appendix A.6 for complete key.)



SCALE
1 : 20,000

0. 1667 Feet

FIGURE 1-6. SOIL MAP OF PRICKETTS POND WATERSHED

→ from what source.
This will impact ARARs.

The normal soil concentrations for three metals found in the Pricketts Brook watershed are as follows: the average concentration for zinc is 50 parts per billion (ppb) at a range of 10 to 300 ppb; the average concentration of lead is 10 ppb at a range of 2 to 200 ppb; and the average concentration of cadmium is 0.06 ppb at a range of 0.01 to 7 ppb (Allaway 1968 and Page 1974).

1.3.3 Geology and Hydrogeology

1.3.3.1 Regional Geology

The CPS/Madison site is located in the Coastal Plain physiographic province. Regional geology is illustrated in Figure 1-7, which presents a cross-section of the Atlantic Coastal Plain. The bedrock surface, underlying a thick wedge of unconsolidated sediments, slopes towards the southwest. The overlying sediment wedge thins to a feather edge along the fall line (the surface exposure of the bedrock and the boundary of the Coastal Plain physiographic province) and thickens to over 6,000 feet at the coastline. These sediments range in age from Cretaceous to Holocene and can be classified as continental, coastal, or marine deposits. The units generally strike northeast to southwest and dip gently to the southeast 10 to 60 feet per mile.

1.3.3.2 Site Geology

Dr. Olsson of Rutgers University was directed by the Superior Court of New Jersey to independently review geologic information contained in documents prepared by Wehran; EFP Associates, Inc.; and CH2M Hill. In his 1987 report to the Court, Dr. Olsson provides a concise description of geology in the vicinity of the CPS/Madison site. His description of the

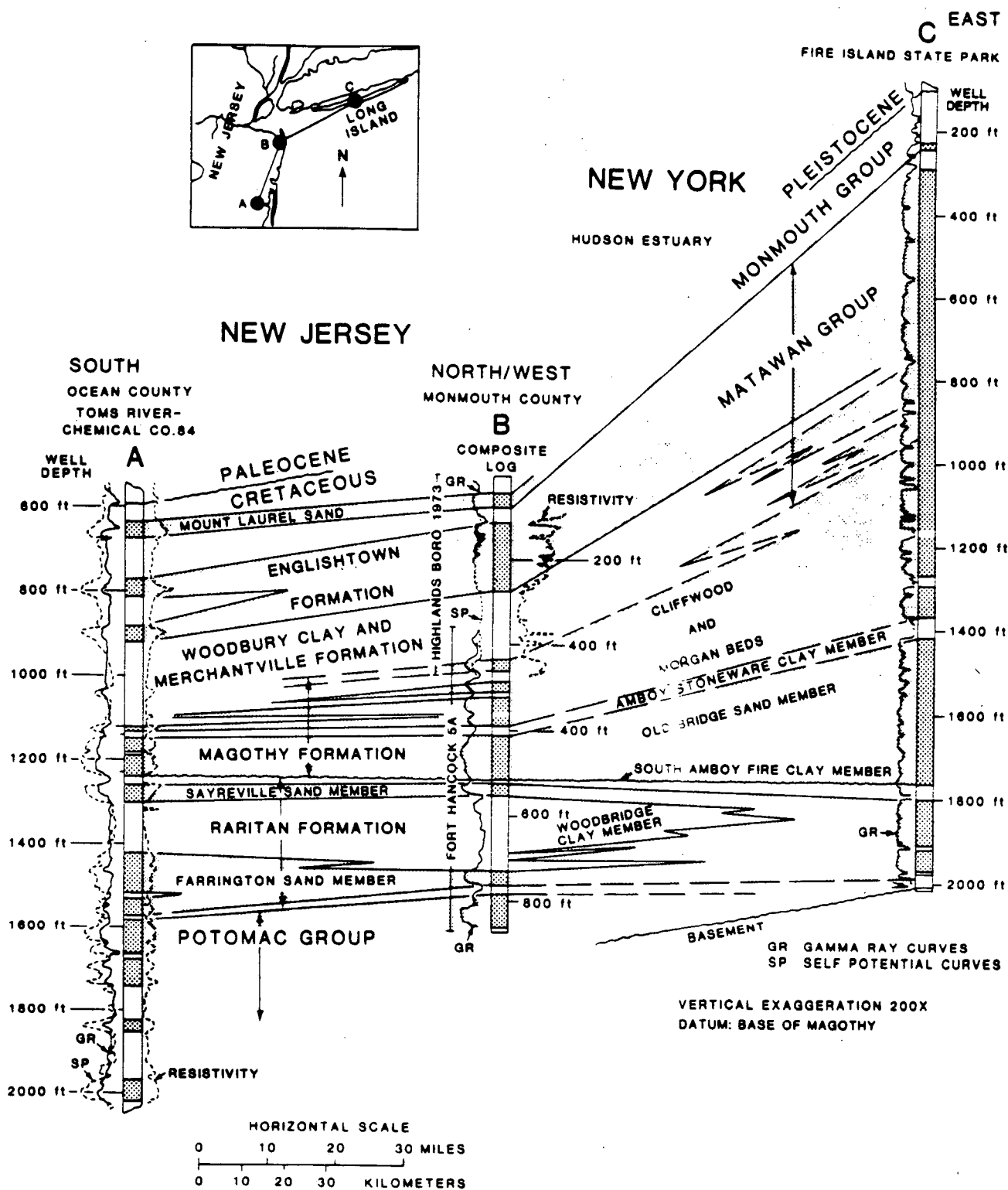


FIGURE 1-7. STRATIGRAPHIC SECTION OF CRETACEOUS DEPOSITS, TOMS RIVER, NEW JERSEY, TO FIRE ISLAND, NEW YORK

four geologic units comprising the Magothy and upper Raritan formations in the Raritan Bay area is presented in Table 1-5. Dr. Olsson reported that the regional dip of the coastal plain strata in the vicinity of the CPS/Madison site is to the southeast at approximately 40 feet per mile. The geologic formations of the coastal plain thicken down dip, creating the characteristic wedge shape of the Coastal Plain strata.

The Cape May formation is the surficial quaternary deposit in the South River region where it occurs in exposures usually 3 to 5 feet thick. Wehran (1983) states that although past studies have documented the existence of Cape May at the CPS/Madison site, in recent studies, Cape May has not been differentiated from the Old Bridge Sand.

Through an evaluation of information gathered from 27 boreholes drilled by NJDEP and Wehran, Dr. Olsson provided an evaluation of the nature and extent of the geologic units that exist from land surface to the top of the Woodbridge Clay. Dames and Moore reports that the thickness of the Old Bridge Sand ranges from 65 to 90 feet within the Pricketts Brook watershed.

At the CPS/Madison site, the Old Bridge Sand is continuous, ranging in thickness from approximately 60 to 85 feet (based on information presented by Dr. Olsson). Dr. Olsson determined that in the northern sector of the site, as defined in Figure 1-8a, the Old Bridge Sand contains many irregularly distributed clay lenses that thicken and thin over short distances and are "most abundant between the elevations of 0 and -50 feet [relative to mean sea level]." In several borings in the southern sector of the site, Dr. Olsson identified a more distinct gray lignitic clay bed within the Old Bridge Sand occurring at an elevation of approximately -30 or -35 feet relative to MSL. Dr. Olsson thinks that this clay bed within the Old Bridge Sand may merge with a

TABLE 1-5. STRATIGRAPHY IN THE VICINITY OF THE CPS/MADISON SITE (Compiled from Olsson 1987)

Formation	Stratigraphic Unit (member)	Description	Environment of Deposition
Magothy	Old Bridge Sand	Fine to medium-grained sand with some coarse-grained beds. Interbeds of light to dark clayey silts and silty clays occur locally.	Deposited in a subaerial deltaic plain (Owens and Sohl 1969). Probably represents point bar sequences of river channel deposits. The thin lignitic silts and clays probably accumulated in small cutoff or abandoned channels.
	South Amboy Fire Clay	White, light blue, or red-mottled clay, which locally may contain dark lignitic beds (Kummel and Knapp 1904). Variable in thickness from 8 to 30 feet. Completely absent in some locations. The clay is often sandy, and where it is absent, it is replaced by sand. Irregular upper surface. May contain a middle sand layer or be overlain by dark gray to black lignitic clay. In places it is a white clayey very fine sand.	Deposited in a subaerial deltaic plain (Owens and Sohl 1969). Clays most probably formed in large abandoned river channels and may be oxbow lake deposits. This interpretation is suggested because the clays thicken and thin rapidly, grade from pure clays to sandy clays, and are absent in places. The white and red-mottled clays for the most part are highly oxidized so that any original organic matter has been lost. In places, however, some organic matter (lignite) is preserved so that the clays are gray in color.
<i>UNCONFORMITY (Approximately 2 Million Years)</i>			
Raritan	Sayreville Sand	Variable in composition but mainly a fine to medium, white micaceous sand. Contains lumps and lenses of white clay. 35 to 40 feet thick north of the Raritan River, but in the vicinity of Sayreville to the south, the Sayreville Sand is very thin or absent. Barksdale (1943) reports that the Sayreville sand is absent in the vicinity of Runyon, adjacent to the CPS/Madison site. Where the Sayreville Sand is absent, the South Amboy Fire Clay rests directly on the Woodbridge Clay.	Deposited in a subaerial deltaic plain (Owens and Sohl 1969). Probably represents point bar sequences of river channel deposits.
	Woodbridge Clay	Gray to dark gray to black laminated micaceous silt, clay, and very fine sand. Lignite is prevalent and often is very abundant in some beds. Siderite or ironstone concretions are common and may form continuous layers. Widespread throughout the Raritan Bay area.	Deposited in a subaerial deltaic plain (Owens and Sohl 1969). Laminated, lignitic, micaceous sands, silts, and clays indicate deposition in overbank swampy environments. Marine fossils in parts of the Woodbridge suggest that these environments were influenced by nearshore processes.

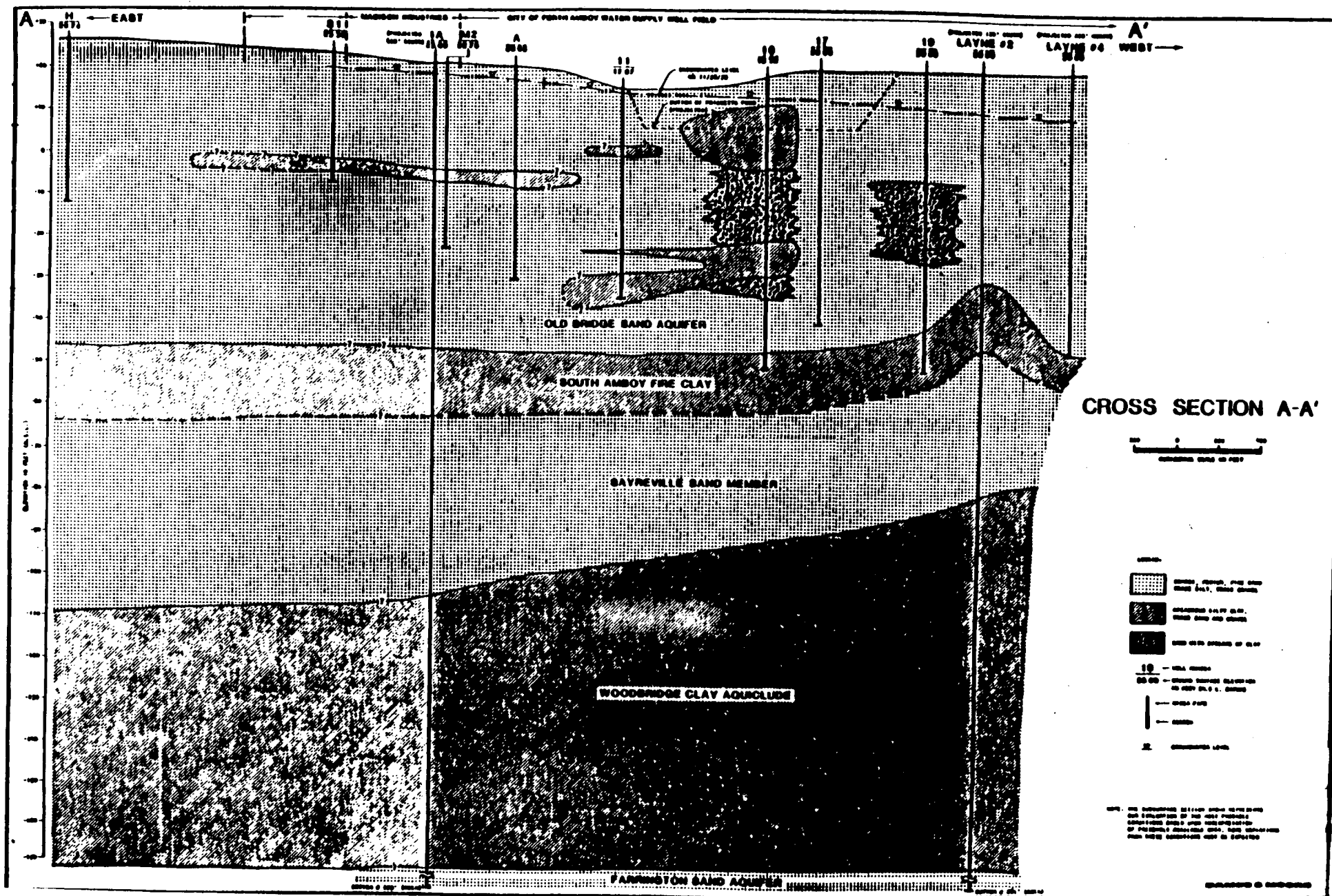


FIGURE 1-8a. CROSS SECTION (A-A') OF STUDY AREA

Source: Dames and Moore 1980

See Figure 1.8b for line of section.

locally thick South Amboy Fire Clay. Dr. Olsson's clay bed is probably the same as that depicted in Dames and Moore's (1980) east/west cross section of the site (see Figure 1-8a [Figure 1-8b is the line of section along which Figure 1-8a was constructed]). Based on Dr. Olsson's evaluation of the boring log data, the lower contact of the Old Bridge Sand in the southern sector ranges between -40 and -50 feet MSL. In the northern sector, the lower contact of the Old Bridge Sand occurs between -54 and -60 feet MSL. Dames and Moore reported that the thickness of the Old Bridge Sand ranged from 65 to 90 feet within the Pricketts Brook watershed.

Wehran (1983) reports that the organic carbon content of the Old Bridge Sand is low, averaging 0.10 percent for the Old Bridge Sand as a whole--0.011 percent for the "predominant clean sands," approximately 1.0 percent for the "subordinate dark gray sands," and 1.32 percent for the "infrequent layers of lignitic clay."

The primary purpose of Dr. Olsson's study was to investigate the nature and extent of the South Amboy Fire Clay across the site. He determined that in the southern sector, the South Amboy Fire Clay is encountered at elevations from -40 to -50 feet MSL, based on borehole information. None of the boreholes in the southern sector penetrated the lower contact of the South Amboy Fire Clay, thus the Clay's exact thickness in the southern sector is unknown. In boreholes in the northern sector of the site, Dr. Olsson determined that the South Amboy Fire Clay occurs in an interval between approximately -54 to -75 feet MSL. In his report to the Superior Court of New Jersey, Dr. Olsson presented several conclusions regarding the nature and extent of the South Amboy Fire Clay beneath the site, including the following:

- A South Amboy Fire Clay "interval" approximately 20 feet thick occurs beneath the CPS/Madison site. At the CPS/Madison site, the South Amboy Fire Clay contains clay layers that are characteristic of the unit but are not



Source: Dames and Moore 1980

continuous. In the northern sector of the site, the South Amboy Fire Clay clays are replaced by sand. Dr. Olsson states that, "In many cases, thin streaks of white clay and white clay matrix in the sand are all that remain of the fire clay."

- Dr. Olsson stated that, "In the northern sector of the site, the South Amboy Fire Clay is lignitic and is darker gray in color and less typical of the fire clay. This has lead to some confusion on the identification of the fire clay."
- Dr. Olsson also stated that, "The clays of the South Amboy Fire Clay are too thin and most probably discontinuous beneath the northern sector of the CPS/Madison site to serve as a basal confining layer for a bentonite slurry containment wall." Dr. Olsson thought that it was reasonable to conclude that the South Amboy Fire Clay is continuous across the southern sector of the site.

The Sayreville Sand, which occurs stratigraphically below the South Amboy Fire Clay in the Raritan Bay area, was determined by Dr. Olsson not to be "a viable unit" beneath the CPS/Madison site. He stated that, "The name can be applied to a few intervals of sand between the South Amboy Fire Clay and the Woodbridge Clay, but for the most part the Sayreville sand is not distinguishable." Wehran (1983) notes that, "At the site [the Sayreville Sand] is significant only that where the Fire Clay is absent (northeast boundary of CPS property), the Sayreville may be included in the 'Old Bridge' aquifer."

Dr. Olsson's major conclusion regarding the Woodbridge Clay is that it "is an easily identifiable and widespread horizon throughout the site area. It can be identified by its characteristic lithology and gamma-ray log signature. As such, it provides a useful datum with which to reference the stratigraphic units above." Based on the available borehole information, Dr. Olsson determined that the upper surface of the Woodbridge Clay in the northern sector of the site occurs at an elevation between -72 to -76 feet MSL. None of the borings

studied by Dr. Olsson for the southern sector of the site penetrated the Woodbridge Clay. Wehran (1983) states that the thickness of the Woodbridge Clay is reported to be between 50 to 90 feet. A stratigraphic section presented in Dr. Olsson's report to the Superior Court of New Jersey, however, indicates that the thickness of the Woodbridge Clay in the Raritan Bay region is between 15 to 25 feet. Wehran (1983) claims that the Woodbridge Clay is more shallow at Pricketts Pond (occurring at a depth of approximately 65 feet at Pricketts Pond) and "deeper (averaging 80 feet) along the perimeter of CPS and Madison." Based on limited information gathered from cross sections constructed by Dames and Moore (1980), the Woodbridge Clay extends to an elevation of approximately -170 feet MSL thereby making it approximately 96 feet thick (given Dr. Olsson's estimate of the upper contact of the clay [-72 to -76 MSL]).

Below -170 feet MSL is the Farrington Sand. The local thickness of the Farrington Sand was not presented in any documents reviewed for this Feasibility Study, but the Farrington Sand is reported to be 0 to 25 feet thick in the Raritan Bay area (Dorf and Dr. Olsson 1983).

1.3.3.3 CPS/Madison Well Field

The information available for this study indicated that 98 groundwater monitoring, groundwater observation, and water supply wells exist on or in the immediate vicinity of the CPS/Madison properties. Table 1-6 presents a list and description of each of the well "series" (e.g., "WCC-", "DW-", "WE-"). To facilitate the evaluation of well construction for the purposes of creating water level contour maps and evaluating groundwater monitoring data, all available well construction information was compiled into a table. This table is presented as Appendix A.7 to this report. Appendix A.8 presents the well logs and well

TABLE 1-6. DESCRIPTIONS OF WELL SERIES

Well Series	Description
No.1 through No. 32	Perth Amboy Bennet Suction Line Wells
Layne 1A, Layne 1 through Layne 5	Perth Amboy Water Supply Wells
A through H	Observation wells installed by Ad-Tek Engineering prior to 1975
Schoor #1 through Schoor #4	Wells installed by Schoor Engineering in 1973
MI-T1 (also called T-1)	Pumping well located on Madison Industries property
M-1 through M-6	Monitoring wells installed by Converse Consultants and located on Madison Industries property
S-1 through S-3	Monitoring wells installed by NJDEP prior to 1977 and located on CPS Chemical property
WCC-1 through WCC-7, WCC-9, WCC-11 through WCC-16	Monitoring wells installed by Woodward Clyde Consultants in 1981
DEP-1 through DEP-4	Monitoring wells installed by NJDEP in 1982
WE-1 through WE-4	Monitoring wells installed by Wehran Engineering in 1983 and located on CPS Chemical property
T-2 and T-3	Groundwater withdrawal wells (other information not available)
DW-1 through DW-7	Monitoring wells installed by Wehran Engineering in 1988

construction information that were available for the preparation of this report. Well construction information was completely missing for 16 wells.

A map providing the accurate locations of all wells in the vicinity of the site was not available for incorporation into this study. Moreover, survey coordinates were not available for any of the monitoring wells. As a result, Figure 1-3, which presents well locations, shows only the approximate locations of 97 of the 98 wells installed in the study area. The approximate location of wells L-1A, SE-7, and No. 14 are not available.

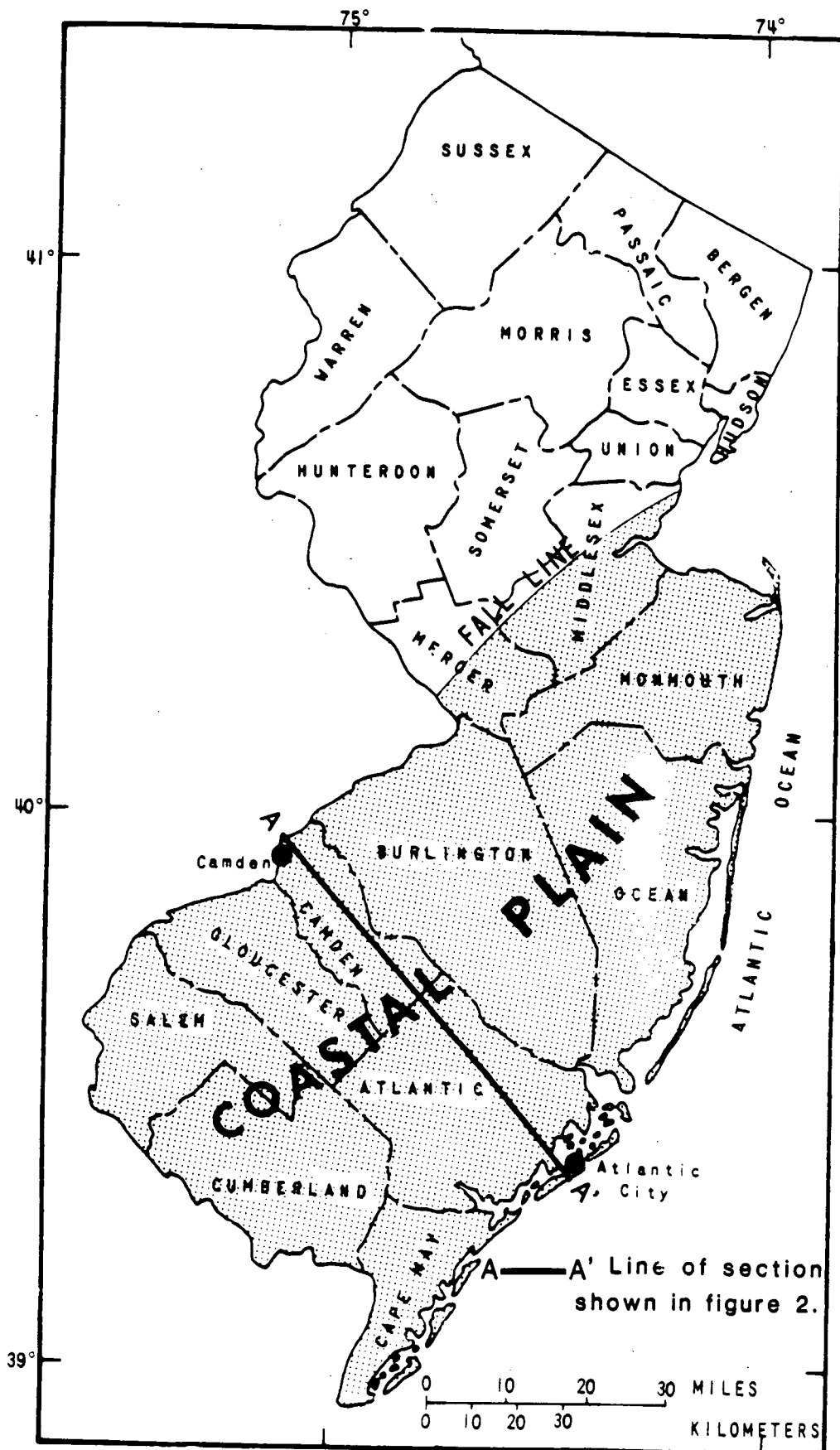
Wells at the site vary greatly in construction. Based on the available information, only the "WE-" and "DW-" series wells are adequately constructed with respect to current guidance. Because no analytical data existed for the "WE-" series wells and the "DW-" series were not installed until late 1988, it was necessary to evaluate both water level and analytical data from wells that may have been constructed inadequately. Therefore, for the purposes of this FS, data from those wells screened in the Old Bridge Aquifer that had been monitored for at least one of the five Dames and Moore indicator constituents (i.e., zinc, lead, cadmium, methylene chloride, and 1,1,2,2-tetrachloroethane) and for which well depths and locations were known were evaluated. The identification of the geologic unit monitored by each of the wells was determined by comparing the well depth to cross sections in Dames and Moore's report (1980) and/or by interpreting an available boring log. The list of wells meeting the above criteria is presented in Appendix A.9. Well No.s 10, 16, and 19 are screened, at least in part, in the South Amboy Fire Clay; however, these wells were considered to monitor the Old Bridge Aquifer.

Several monitoring well (or borehole) identification numbers are inconsistent between the documents reviewed. Consequently, due to lack of information, the following assumptions were made: (1) the Ad-Tek wells A, B, and C are equivalent to Perth Amboy wells A, B, and C; (2) wells B-10, B-11, and B-13 are the same as Bennet Suction Line wells 10, 11, and 13; (3) wells MI-1 through 6 are the same as wells M-1 through 6; (4) well MI-T1, M1-T1, and T-1 are the same; and (5) Schoor wells 1 through 4 are the same as wells SE-1 through 4. In addition, difficulties were encountered in distinguishing between some of the wells in the "WCC-" series. As a result, the following assumptions were made: (1) well WCC-11N is the same as WCC-11M; (2) well WCC-2 is the same as WCC-2M; (3) wells WCC-9S, 11S, 15S, and 16S, are the same as wells WCC-9VS, WCC-11VS, WCC-15VS, and WCC-16VS, respectively; (4) well WCC-11C is the same as WCC-11D; (5) well WCC-15W is the same as WCC-15M; (6) WCC-15E is the same as WCC-15S; and (7) WCC-12 is the same as WCC-12M.

1.3.3.4 Regional Hydrogeology

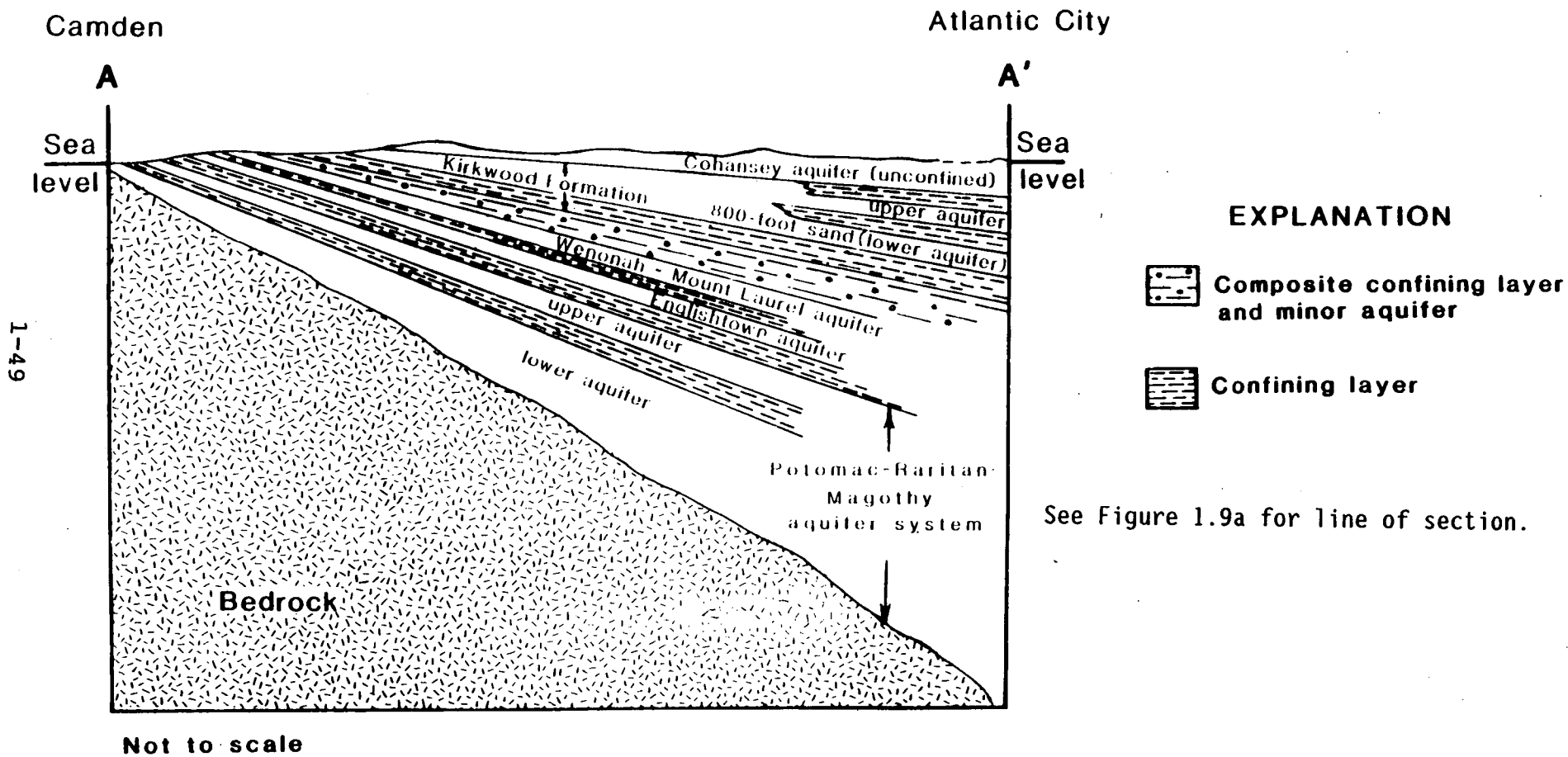
The entire Coastal Plain, a wedge-shaped mass of unconsolidated sediment, is essentially an independent and isolated hydrologic system. It is separated from the Appalachian Highlands by the Fall Line, which extends northeast along the Delaware River and through Mercer and Middlesex Counties. The Coastal Plain is surrounded by salty or brackish water, bounded by the Delaware River on the west, the Delaware Bay on the south, the Atlantic Ocean on the east, and the Raritan Bay on the north (see Figure 1-9a).

The geologic units of the Coastal Plain, alternating layers of clay, silt, sand and gravel, act as either aquifers or confining layers, as depicted on Figure 1-9b (Figure 1-9a shows the line of section along which Figure 1-9b was constructed).



Source: Walker 1983

FIGURE 1-9a. LOCATIONS OF CROSS SECTIONS IN THE COASTAL PLAIN OF NEW JERSEY



Source: Walker 1983

FIGURE 1-9b. DIAGRAMMATIC HYDROGEOLOGIC SECTION OF THE NEW JERSEY COASTAL PLAIN

The units have been divided into five major aquifer systems (a hydrologically connected aquifer(s) and confining layer[s])--the Potomac-Raritan-Magothy (P-R-M) Aquifer system, the Englishtown Aquifer, the Wenonah-Mount Laurel Aquifer, the lower sand of the Kirkwood Formation, and the Kirkwood-Cohansey Aquifer. The P-R-M Aquifer system is the most widely used aquifer system in the Coastal Plain. In the northern part of the Coastal Plain (i.e., Raritan Bay Area), the P-R-M Aquifer system consists of two aquifers--the Farrington Aquifer (Raritan age) and the Old Bridge Aquifer (Magothy age), which are separated by the Woodbridge Confining Layer.

The components of the long-term hydrologic budget for the Coastal Plain are precipitation, streamflow, and water loss. Average precipitation is about 44 inches per year. Streamflow and water loss are about 20 and 24 inches per year, respectively. More than 75 percent of the streamflow in the Coastal Plain is derived from groundwater recharge. Water loss occurs primarily by evapotranspiration. The Coastal Plain is a groundwater-dominated hydrologic system; therefore, the amount of water stored in surface-water reservoirs is small compared to the quantity stored in the ground. Consequently, groundwater is the primary water supply source.

The natural hydrologic cycle in the Coastal Plain has been modified by man's activities. Three activities have the most significant impact on the water budget--disposal of direct runoff into storm sewers, groundwater withdrawals, and disposal of used water to sanitary sewers. The overall effect of these activities on the water budget is to increase the rate of outflow to the ocean.

A regional decline in groundwater levels has changed the direction of groundwater flow. Induced recharge and saltwater

encroachment have resulted from the changes in flow direction. Where head gradients are large enough, water can be induced to flow from adjacent surface-water bodies or through confining beds. If recharge from precipitation and induced infiltration is insufficient to replace groundwater from heavily pumped areas close to the saltwater-freshwater interface, the interface may advance toward pumping centers and result in saltwater encroachment of the Old Bridge Aquifer.

1.3.3.5 Site Hydrogeology

Two major aquifers, the Old Bridge Sand and the Farrington Sand, exist beneath the CPS/Madison site. As reported by Dames and Moore (1980) and Ad-Tek (1975), both Aquifers are used to provide water to the communities (i.e., Perth Amboy, Sayreville, and Madison Township) and industries in the vicinity of the CPS/Madison site. As discussed previously, the Old Bridge Sand extends from land surface (or just below the veneer of the Cape May Formation) to approximately 60 to 85 feet. The water table in the Old Bridge Sand ranges from approximately 0 to 5 feet BLS. The Old Bridge Sand is separated from the deeper Farrington Sand Aquifer by approximately 120 feet (Dames and Moore 1980) of the clays, silts, and sands of the discontinuous South Amboy Fire Clay and Sayreville Sand units and the more laterally continuous and impermeable Woodbridge Clay. Based on a cross section presented by Dames and Moore (1980), previously presented as Figure 1-8, the contact between the Farrington Sand and the Woodbridge Clay at the CPS/Madison site occurs at an elevation of approximately 170 feet. Note, however, that the Dames and Moore cross section depicts only two wells that penetrate the Farrington Sand. Dames and Moore (1980) report that no information exists regarding the hydraulic connection between the Old Bridge and Farrington Sand Aquifers. Post-1980 information concerning the hydraulic connection between the Old Bridge and

Farrington Sands was not available during the preparation of this FS. Due to the lack of investigation of the Farrington Sand Aquifer at the CPS/Madison site, most of the information presented in this chapter will focus primarily on the Old Bridge Aquifer. Further study would be required to more adequately characterize the Farrington Sand Aquifer at the CPS/Madison site.

The hydraulic properties of the geologic units underlaying the CPS/Madison site are presented in numerous reports. Table 1-5 presents a summary of the values that have been derived for conductivity, transmissivity, storativity, porosity, and specific yields of the various units. In general, the Old Bridge Aquifer is characterized by high to very high permeability and transmissivity. Transmissivities greater than $1.5 \text{ cm}^2/\text{sec}$ represent good aquifer yields. The calculated storativity value is low relative to the typical range for most unconfined aquifers (i.e., 0.01 to 0.30).

Wehran reports that the Cape May formation, "increases the effective intake area of the Old Bridge Sand by transmitting water that falls upon areas in which the Cape May is underlain by clays to areas in which the formation is underlain by Old Bridge Sand." Ad-Tek describes Cape May as being "extremely permeable" and "hydrologically transparent."

Recent information regarding the locations and operation of withdrawal and injection wells in the vicinity of the CPS/Madison site was not provided in the available documents. In particular, information (e.g., pumping rates, depth, and screened interval) that would assist in characterizing the effect of Madison Industries' pumping well MI-T1 on the groundwater flow system was unavailable. Additionally, information contained in Wehran's report (1989), indicates that a water supply well is located on

CPS property. Information regarding the operation of the CPS production well was unavailable for this study, however.

CPS/Madison is located 2,000 feet northeast of the Runyon (Perth Amboy) well field and water supply station that provides water to the city of Perth Amboy. The well field consists of four active pumping wells (5, 6, 7, and 8) that are screened in the Old Bridge Aquifer. Well yield is between 0.72 and 1.44 mgd. The well field is recharged by Tennent Pond. In addition, the Sayreville Borough maintains a well field approximately .25 miles northwest of the CPS/Madison site. The well field consists of 12 wells, 11 of which are screened in the Old Bridge Aquifer and 1 which is screened in the Farrington Aquifer. TRC (1987) reports that the Sayreville well field is recharged by three ponds into which the Sayreville Borough pumps water from the South River. The maximum total daily withdrawal from these wells is 3.5 mgd, and the total daily average pumping rate is 2.0 mgd. Figure 1-1 shows the location of the Perth Amboy and Sayreville well fields. TRC's Draft Remedial Investigation of the Evor Phillips site (1987) presents some of the most recent information regarding water supply wells in the vicinity of the CPS/Madison site. TRC reports that, "All of the wells at the Sayreville and Perth Amboy wellfields are being pumped continuously, the exceptions being wells that are currently being redeveloped and wells that are inactive due to saltwater intrusion or groundwater contamination." Table 1-7, from TRC's remedial investigation (RI) on Evor Phillips, presents the status of selected wells in the Perth Amboy and Sayreville well fields. Table 1-8, also from TRC's RI, contains information regarding the wells composing the Perth Amboy well field.

Artificial recharge schemes have been developed to increase pumpage from the Old Bridge Aquifer. It is unclear whether these plans have been implemented. As described for the Evor Phillips

TABLE 1-7. BOROUGH OF SAYREVILLE
MUNICIPAL WELLFIELD INFORMATION

Well Identification	Location ¹	Date of Construction	Depth (ft)	Pump Capacity (ft)	Yield (GPM)	Formation
A	Bordentown	1959	76	350	375	Old Bridge
B	Bordentown	1958	81	700	1,012	Old Bridge
C	Bordentown	1958	73	350	644	Old Bridge
D	Bordentown	1958	75	350	636	Old Bridge
E	Bordentown	1957	62	350	402	Old Bridge
F	Bordentown	1957	74	350	662	Old Bridge
G	Bordentown	1960	87	360	402	Old Bridge
H	Bordentown	1960	83	350	302	Old Bridge
I	Bordentown	1960	99	700	820	Old Bridge
K	Bordentown	1965	90	325	737	Old Bridge
L	Bordentown	1965	93	300	375	Old Bridge
M	Bordentown	1967	280	1,000	1,236	Farrington
P	Morgan	1967	280	1,200	1,218	Farrington
O	Morgan	1966	248	500	--	Farrington
R	Morgan	1980	116	400	430	Old Bridge
S	Morgan	1980	291	1,250	1,455	Farrington
T	Morgan	1982	141	400	503	Old Bridge

¹ The Bordentown Plant is located approximately 3,000 feet southwest of the EPLS site. The Morgan Plant location is a significant distance from the EPCL site such that it impacts from the site on the wells are not anticipated.

(TRC 1987)

TABLE 1-8. CITY OF PERTH AMBOY
MUNICIPAL WELL FIELD INFORMATION

Well No./ Identification	Date of Construction	Depth (ft)	Pump Capacity (ft)	Yield (GPM)	Formation
5	1958	78	500	500	Old Bridge
6	1983	80	700	700	Old Bridge
7	1983	82	1000	1000	Old Bridge
8	1983	80	1000	1000	Old Bridge
40 Vacuum Wells	1958-1984	45-60	2800	70	Old Bridge

(TRC 1987)

Facility (TRC 1987), two of the artificial recharge operations involve impounding streams and inducing infiltration by a ring of shallow wells around the impoundment.

Depending on the location and pumping rate and/or recharge rate of the wells described above, the natural groundwater flow system can be significantly impacted. This has not been thoroughly investigated and therefore, the impact can only be speculated. It is expected that piezometric gradients would increase towards the Perth Amboy and Sayreville well fields. Groundwater flow directions would also be expected to be skewed towards these well fields.

In order to evaluate groundwater flow, water level contour maps were constructed using November 1988 water level and staff gauge data presented in Wehran's report (1989). Modifications to the maps were then made manually.

This discussion and the discussion of vertical groundwater flow that follows assume that the 1982 and 1988 data are of sufficient quality to support detailed analysis. The absence of verifiably accurate survey data for the wells calls this assumption into question. While differences in the surveyed location could alter the interpretation of the horizontal groundwater flow, this effect should be minor. Interpretations of vertical flow, however, could change drastically with small changes in vertical measurement. It is recommended that any decisions based on these interpretations of groundwater flow be preceded by a field effort to verify the accuracy of the data.

The approximate locations of the monitoring wells were derived from maps of the site provided in Wehran (1989) and CDM (1988). The monitoring well location map is presented as Figure 1-3 on page 1-7. Well clusters were assigned one set of well

coordinators for ease in plotting the isoconcentration maps. The "WCC-" cluster wells were assigned the location corresponding to the medium ("M") well whenever possible, and the "DW-" cluster wells were assigned the shallow well location. SURFER uses the available data points to calculate values for each node on a grid, the size of which is specified by the user. The size of the grid is 135 units in the X direction and 55 units in the Y direction. The grid nodes were calculated using the kriging algorithm. All of the data points were used in calculating each grid node.

Figure 1-10 presents a potentiometric surface map for the Old Bridge Aquifer at the CPS/Madison site, which was constructed by Wehran (1989) using water levels measured in November 1988. Based on this map, Wehran concluded that the most recently established groundwater flow direction in the Old Bridge Sand is generally southwesterly, consistent with the findings of their 1987 report. Wehran notes that the map reflects the influence of groundwater withdrawal at the Madison Industries pumping well MI-T1. Figures 1-11 and 1-12 present potentiometric surface maps for the Old Bridge Aquifer contoured for this study using Wehran's November 1988 water level data. Figure 1-11 presents groundwater flow in deep wells at the site. ("Deep wells" are either deeper than -11 feet in elevation or greater than 30 feet deep [for some wells at the site a reference elevation did not exist, e.g., top of casing or land surface elevation, so that it was impossible to determine the elevation of the well bottom]). Figure 1-12 presents groundwater flow as determined by water levels measured in shallow wells and elevations measured in staff gauges established by Wehran for Pricketts Brook and Pricketts Pond.

The maps developed by Wehran and the map developed for this FS present similar representations of shallow groundwater flow in the vicinity of Pricketts Pond. From Figure 1-12, it appears

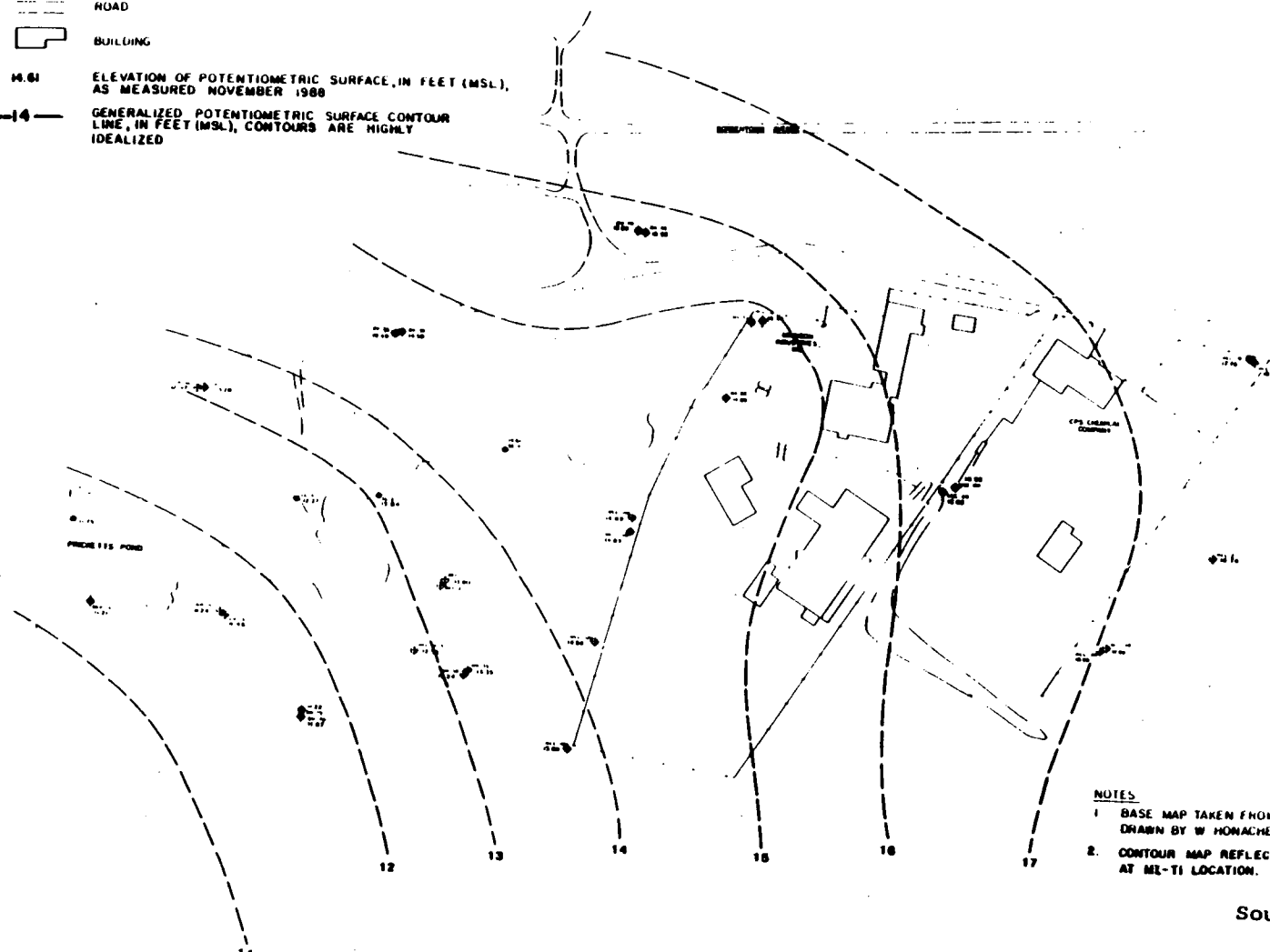
- LEGEND:
- MI-T1 MADISON PUMPING WELL
 - MI-Q2 WCC-5 MONITORING WELL INSTALLED BY OTHERS
 - DEP 2 MONITORING WELL INSTALLED BY NJDEP
 - DEP 40 MONITORING WELL INSTALLED BY WEHRAN
 - SG 3 STAFF GAUGE INSTALLED BY WEHRAN

- FENCE LINE
- WATER LIMITS
- ROAD
- BUILDING

M. 61 ELEVATION OF POTENTIOMETRIC SURFACE, IN FEET (MSL), AS MEASURED NOVEMBER 1988

14 GENERALIZED POTENTIOMETRIC SURFACE CONTOUR LINE, IN FEET (MSL), CONTOURS ARE HIGHLY IDEALIZED

1-58

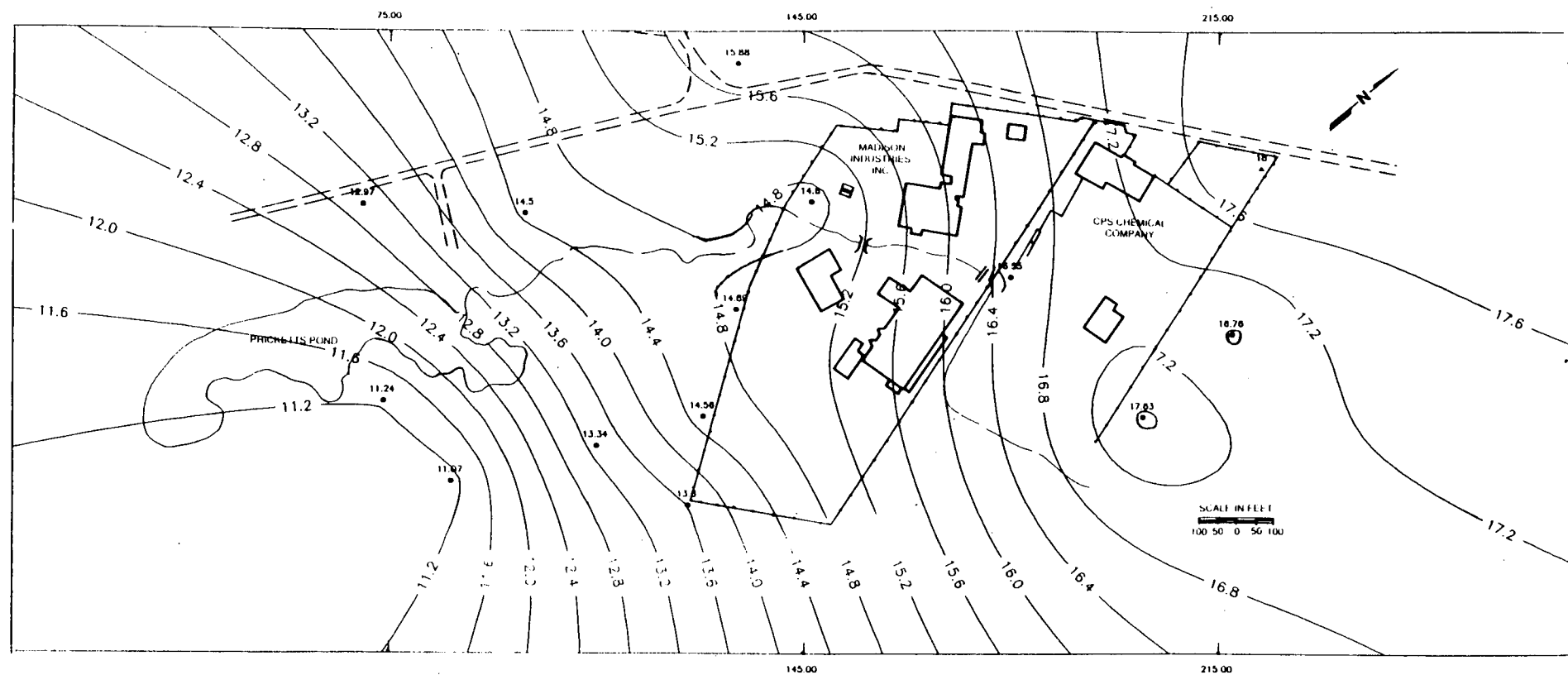


NOTES

1. BASE MAP TAKEN FROM GENERAL LOCATION MAP PROVIDED BY NJDEP, DRAWN BY W. HONACHEFSKI.
2. CONTOUR MAP REFLECTS INFLUENCE OF MADISON PUMPING WELL AT MI-T1 LOCATION.

Source: Wehran 1989

FIGURE 1-10. POTENTIOMETRIC SURFACE MAP OF THE OLD BRIDGE AQUIFER



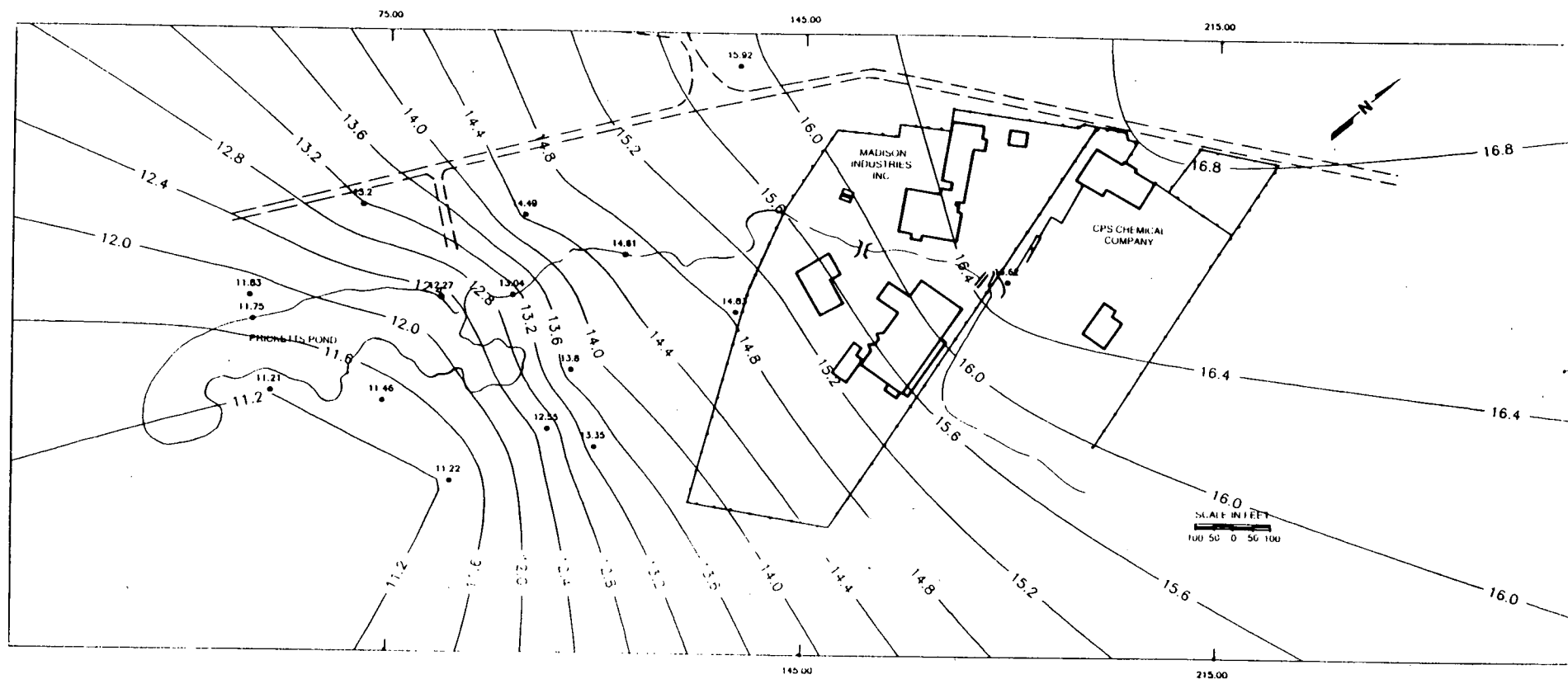
LEGEND:

• Well or Staff Gauge

— 16.0' — Water Level Contour, feet above mean sea level

Note: All locations are approximate.

FIGURE 1-11. WATER LEVEL ELEVATIONS IN THE STUDY AREA'S DEEP WELLS (FEET)



LEGEND:

• Well or Staff Gauge

— 16.0 — Water Level Contour, feet above mean sea level

Note: All locations are approximate.

FIGURE 1-12. WATER LEVEL ELEVATIONS IN THE STUDY AREA'S SHALLOW WELLS (FEET)

that (1) Pricketts Brook is a gaining stream below Staff Gauge 4 to the confluence of Pricketts Brook and Pricketts Pond, (2) groundwater is discharging to the northern portion of Pricketts Pond, and (3) the relationship between groundwater and the southern portion of Pricketts Pond is unclear.

Both maps show that groundwater flows in a southwest direction from the site towards Pricketts Pond. In contrast to Wehran's potentiometric surface map, the shallow groundwater flow map developed for this FS does not indicate conspicuous influence of groundwater withdrawal at well MI-T1. Wehran's map was contoured using both shallow and deep water level measurements and was apparently contoured presupposing influence from well MI-T1. Shallow well data in the vicinity of MI-T1 is lacking. Consequently, if shallow wells were monitored in the vicinity of MI-T1, Figure 1-12 might exhibit more evidence of influence from the pumping well. Figure 1-11, which depicts deeper groundwater flow, illustrates this influence. Nevertheless, the apparent impact of MI-T1 on shallow groundwater flow is evident in Figure 1-12. Specifically, above Staff Gauge 4, groundwater no longer discharges to Pricketts Brook as might be expected, since streams most commonly act as discharge zones. On the contrary, above Staff Gauge 4, the water level contours show no influence from the Brook. Well MI-T1 may be influencing groundwater flow as far downgradient as Staff Gauge 4, such that above Staff Gauge 4, groundwater may be discharging to pumping well MI-T1 rather than Pricketts Brook. It should be noted that conclusions based on one round of water level measurements should be considered with caution since there may be numerous reasons for the observed groundwater flow patterns.

Figure 1-11, the potentiometric surface determined by water levels measured in the deeper wells, depicts generally southwesterly groundwater flow. One area of lower water level

elevation occurs along the western boundary of the Madison Industries property, and an area of higher elevation occurs along the southeastern corner of the CPS property. The area of lower water level elevation is probably related to groundwater withdrawal from well MI-T1. Wehran's report indicates that the November 1988 water levels were measured during pumping of well MI-T1. Although the relative groundwater low is depicted as centered around well MI-02, the low would probably extend northeasterly towards well MI-T1 if water level data existed for well MI-T1 or MI-06. The relative groundwater high centered around well WCC-3 is not as easily explained. Wehran (1989) does not attempt to contour this point at all. There may possibly be an error in the data. However, the relative high could be related to the marsh areas, which exist southeast of the site, as discussed in the following paragraphs.

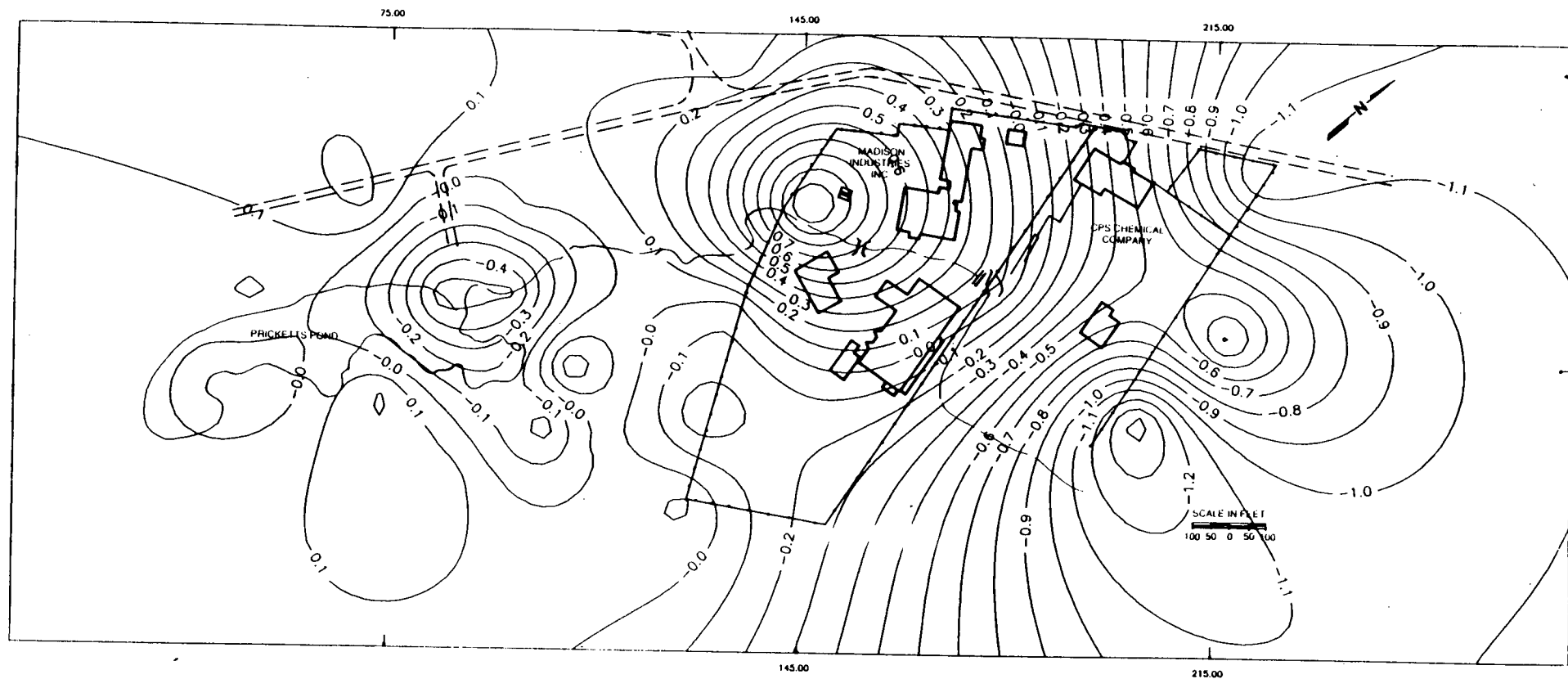
Wehran determined that the horizontal hydraulic gradient is approximately 0.004 foot/foot. Past measurements of the hydraulic gradient in the vicinity of the CPS/Madison site have ranged from 0.0033 to 0.0155 (Dames and Moore 1980), the highest of these occurring between Madison Industries and Pricketts Pond. Hydraulic gradients measured from maps contoured for this FS indicate that shallow hydraulic gradients range from 0.007 foot/foot in the eastern portion of the site to 0.008 foot/foot between Staff Gauge 4 and Pricketts Pond, whereas deeper gradients range from 0.001 foot/foot in the eastern portion of the site to 0.006 foot/foot between Staff Gauge 4 and Pricketts Pond. The highest gradients, as in the past, occur between the Madison Industries (downgradient of Staff Gauge 4) and Pricketts Pond.

Vertical groundwater flow was studied by using SURFER to construct a map of the difference in the shallow and deep water level elevations in feet. SURFER generates a map of the

difference in water level elevations by subtracting like nodes on the two grids used to create the original water level contour maps. The nodal differentials of equal value represent a contour line. This map, presented as Figure 1-13, shows negative numbers where groundwater elevations are greater in the deeper wells than in the shallow wells (i.e., where groundwater flow is vertically upward) and positive numbers where elevations are greater in the shallow wells than in the deeper wells (i.e., groundwater flow is vertically downward). Contours marked with zeroes indicate no vertical gradient.

As seen from Figure 1-13, groundwater flow is vertically upward in the vicinity of the groundwater high depicted in Figure 1-11. The high is not depicted on the map showing shallow water level elevations (see Figure 1-12); however, no shallow water level data exist in the vicinity of the high. As mentioned previously, this high may result from groundwater discharging to the marshes, which occur southeast of the site. The high could also be related to other activities not yet identified.

Although the area northeast, east, and southeast of well MI-T1 is characterized by an upward vertical gradient, in the immediate vicinity of pumping well MI-T1, groundwater is moving vertically downward as would be expected in the vicinity of a pumping well. The area in the vicinity of MI-T1 is the only major area of downward vertical flow on the map. An analysis of vertical flow assists in understanding information gathered from the horizontal flow maps. As previously stated, groundwater appears to discharge to Pricketts Brook downgradient of Staff Gauge 4 and to the northern portion Pricketts Pond. This is apparent from Figure 1-13, where the difference between shallow and deep elevations in this zone is negative, indicating upward flow. There does not appear to be either significant downward or upward groundwater flow beneath the southwestern portion of the



LEGEND:

— -0.2 — Contour of difference in shallow and deep water level elevations, feet

FIGURE 1-13. DIFFERENCE BETWEEN DEEP AND SHALLOW WATER LEVEL ELEVATIONS IN 1988 (FEET)

pond, confirming that groundwater/surface-water interaction in this zone is either unclear or nonexistent. Above Staff Gauge 4, towards the site, groundwater flows vertically downward as it is influenced by groundwater withdrawal from well MI-T1.

Several interpretations of recharge and discharge scenarios at the site have been presented, including the following:

- Wehran's analysis of water levels measured in November 1988 concluded that a downward vertical flow component existed over much of the site. Using monitoring well and staff gauge data, Wehran determined that while groundwater discharges into Pricketts Pond from the north, Pricketts Pond discharges to the groundwater system to the Pond's south.
- On March 16, 1987, NJDEP measured water levels in Pricketts Pond and in the wells in the vicinity of the CPS/Madison site (the wells investigated were not presented in the available information) to resolve the issue concerning whether groundwater in the Old Bridge Aquifer discharges to Pricketts Pond. Correspondence discussing the data from this investigation states that, "the water level in Pricketts Pond is lower than water levels in most of the shallow monitoring wells in the area, and as such, (Pricketts Pond) may possibly serve as a discharge point for shallow groundwater flow. However, a review of water levels in monitoring well clusters such as DEP-1, DEP-2 and DEP-3 indicates a downward hydraulic head....As such, the data indicate that there is a downward component of groundwater flow and that Pricketts Pond may not serve as a discharge point for all the groundwater upgradient of the pond in the Old Bridge aquifer" (correspondence from Andrew M. Cozzi [Geraghty and Miller] to David Tykulsker [Ball, Livingston, & Tykulsker] dated August 5, 1987).
- In 1983, Wehran reported that groundwater discharge to Pricketts Pond was significant. Wehran also reported a "slight" discharge of groundwater to Pricketts Brook. Wehran stated that, "Discharge to the brook at WCC-3 and WCC-6 is intermittent, dependent upon the depth of groundwater and the effects of precipitation events and/or pumping. Away from the brook on CPS property, at WCC-1 and WCC-9, a slight downward component to groundwater movement is evident. Downstream toward Pricketts Pond an upward component to groundwater

movement, as measured in Wells WCC-11 and WCC-15, is indicated."

The vertical hydraulic gradient was calculated for each well cluster monitored in November 1988. Upward vertical gradients ranged in magnitude from 0.0004 to 0.022; downward gradients ranged from 0.004 to 0.011. The greatest vertical gradient (0.022) occurred in the eastern portion of the site, the location of the lowest horizontal hydraulic gradient.

Saltwater Intrusion

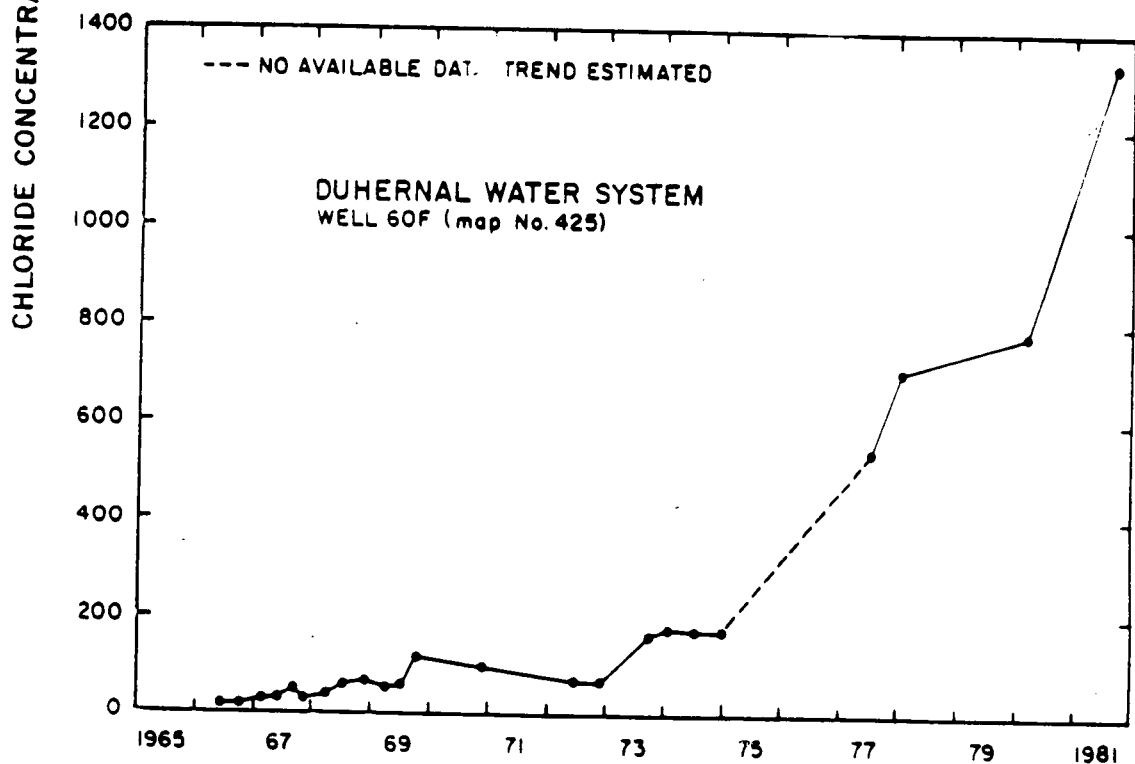
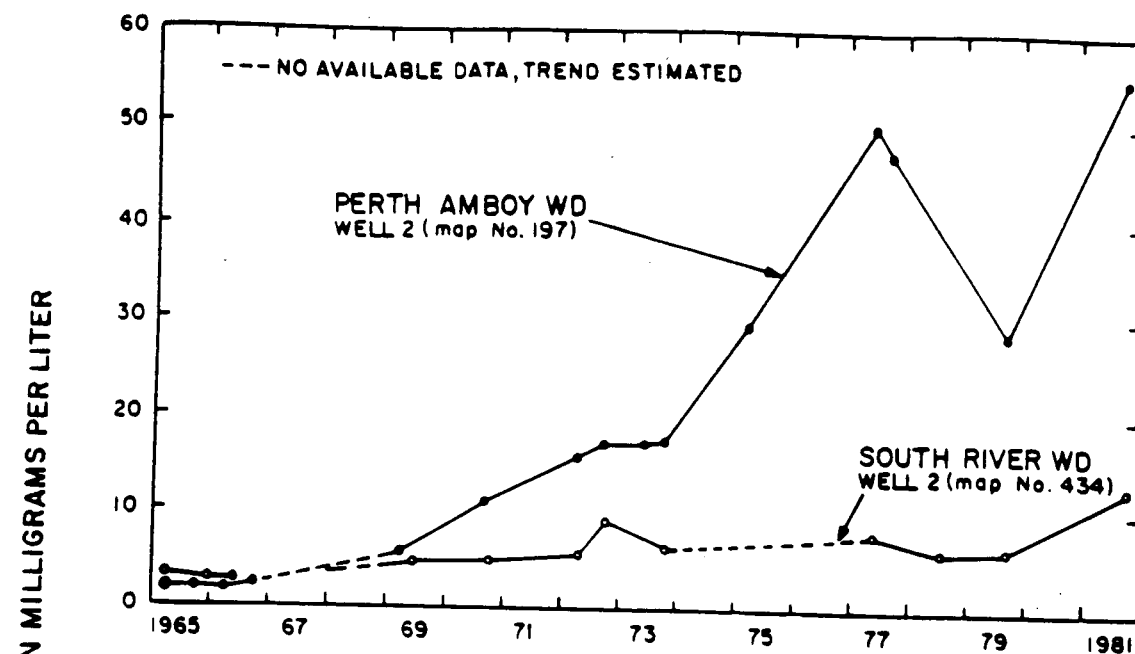
Data obtained from a 1983 USGS publication describing the chloride concentration in groundwater in Middlesex County, indicate that encroachment of saltwater into the Farrington and Old Bridge Aquifers in the Sayreville area of Middlesex County has been reported for about 40 years and is now more extensive. Many production wells have been abandoned in the area. In most cases, saltwater intrusion has resulted from extensive groundwater withdrawals (i.e., causing a reversal in the natural hydraulic gradients).

Chloride concentrations have continued to increase since 1977 in many of the wells in the Farrington Aquifer (see Figures 1-14a and b). For example, the concentration of chloride measured in Perth Amboy well no. 2, near the CPS/Madison facility, shows a marked increase in chloride from 1965 to 1981.

Trends in chloride concentrations in groundwater from wells screened in the Old Bridge Aquifer at the Perth Amboy Water Department well field are presented in Figures 1-14c and d. Because the Old Bridge Aquifer is shallow and/or outcrops in the Raritan Bay area, it is highly susceptible to contamination from direct surface infiltration of saltwater or high chloride

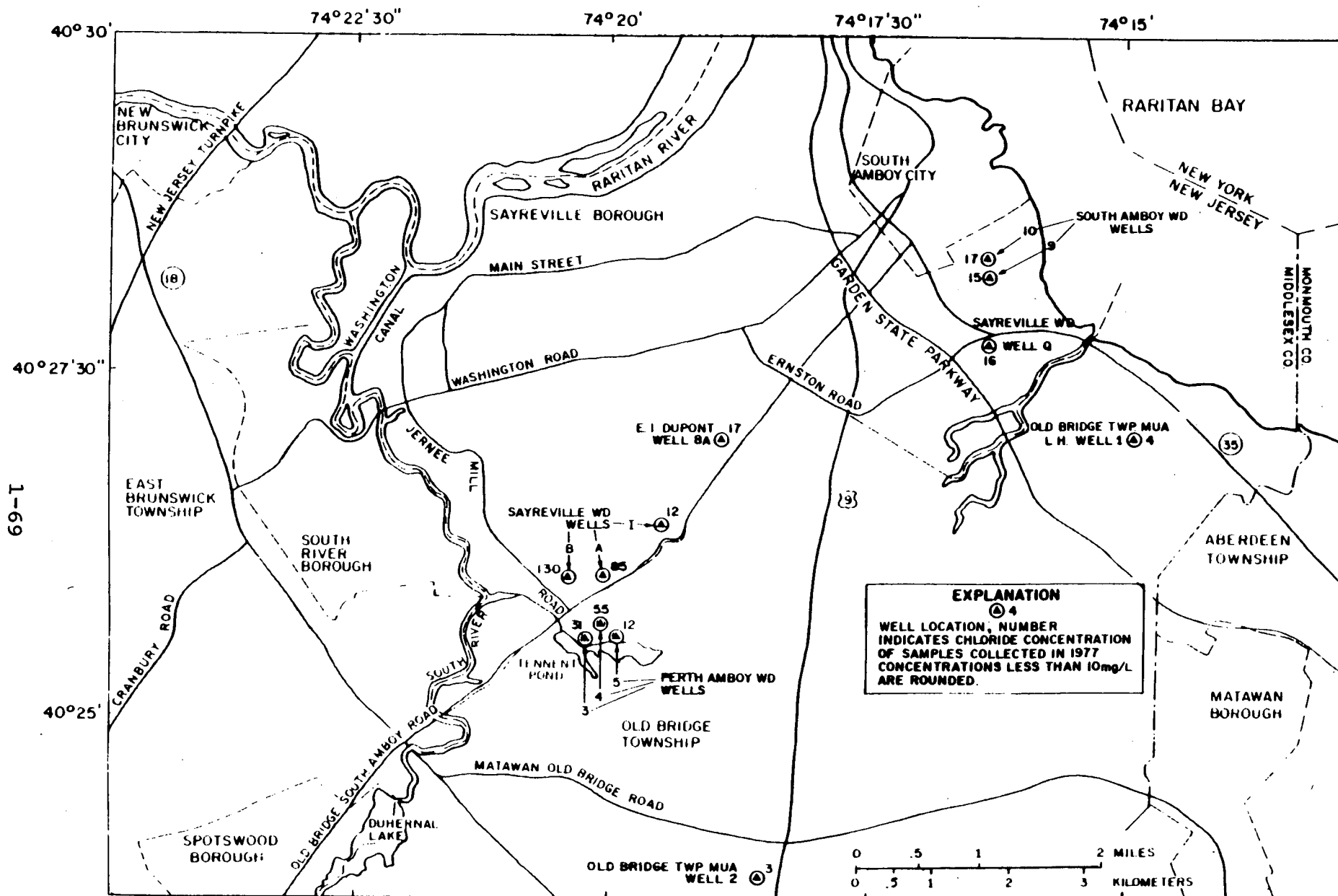
Source: Schaefer 1983

FIGURE 1-14a. MAP OF THE SAYREVILLE AREA, MIDDLESEX COUNTY, SHOWING WELL LOCATIONS, CHLORIDE CONCENTRATIONS, AND GROUND-WATER MOVEMENT IN THE FARRINGTON AQUIFER, 1977



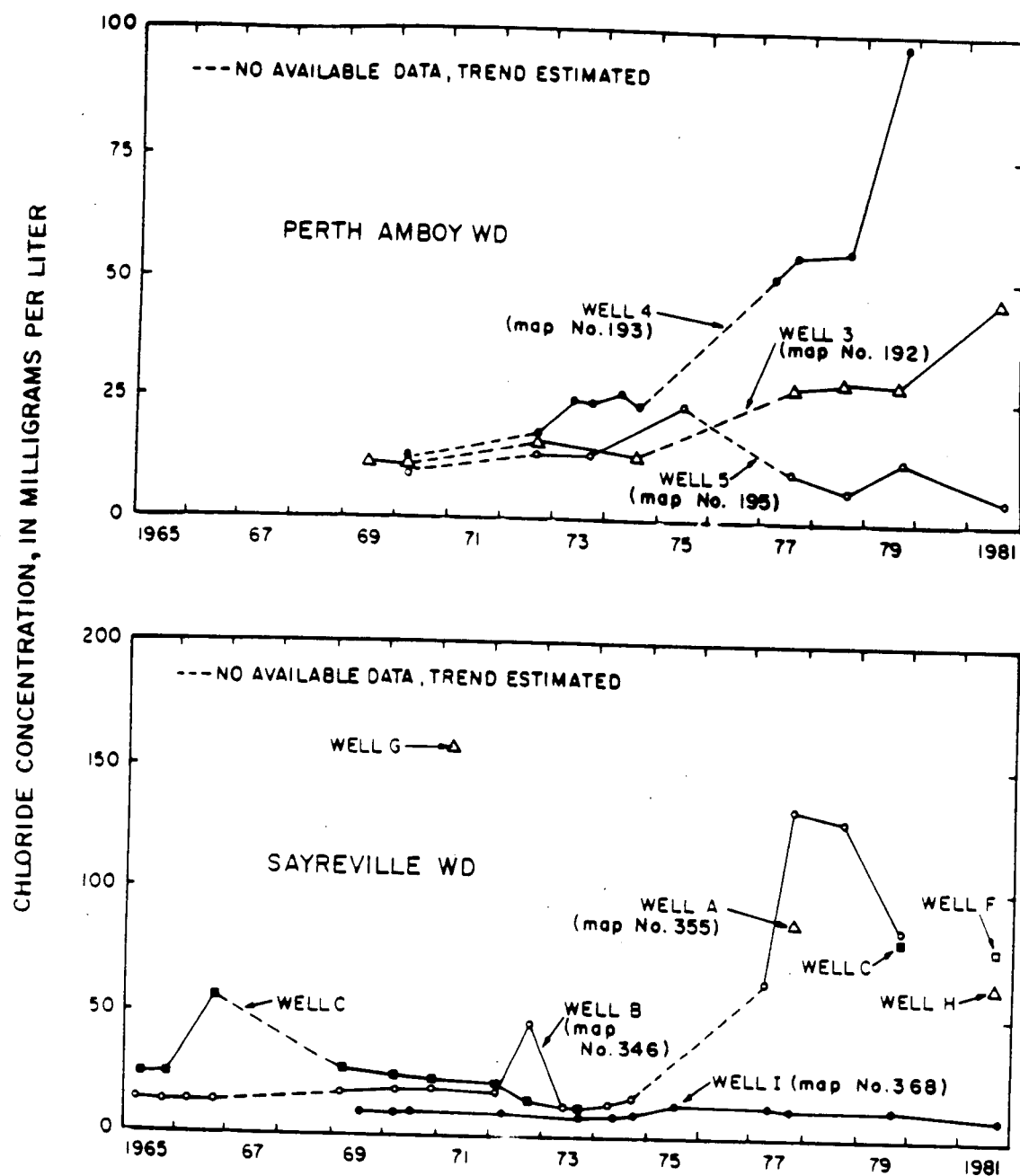
Source: Schaefer 1983

FIGURE 1-14b. CHLORIDE CONCENTRATIONS FROM SELECTED WELLS TAPPING THE FARRINGTON AQUIFER IN THE SAYREVILLE AREA, MIDDLESEX COUNTY, 1965-81



Source: Schaefer 1983

FIGURE 1-14c. MAP OF THE SAYREVILLE AREA, MIDDLESEX, COUNTY, SHOWING WELL LOCATIONS AND CHLORIDE CONCENTRATIONS FROM WELLS TAPPING THE OLD BRIDGE AQUIFER, 1977 (Taken from



Source: Schaefer 1983

FIGURE 1-14d. CHLORIDE CONCENTRATIONS FROM SELECTED WELLS TAPPING THE OLD BRIDGE AQUIFER IN THE SAYREVILLE AREA, MIDDLESEX COUNTY, 1965-1981

leachates from waste disposal areas. Some high chloride concentrations in groundwater are a result of poor waste-disposal practices. Overpumpage of the Old Bridge Aquifer does not appear to cause as serious a threat of saltwater intrusion as compared to the Farrington Aquifer because it is an unconfined aquifer and cone-of-depressions around pumping wells but, screened in Old Bridge Aquifer, are less evident (i.e., aquifer yield¹ is greater in the Old Bridge than the Farrington Aquifer} (Personal communication, Ham Pucci, USGS 1989). }?

1.3.4 Demography and Land Use

1.3.4.1 Surrounding Area

The CPS/Madison site is surrounded largely by industry. Eight-hundred feet northwest of the site is the Evor Phillips Leasing Company Superfund site. Other industries include Lionett Oil Recovery Company, Jersey Billets Division of Easco Company, Forte Pallet, and BG&M, all northeast of the CPS/Madison site.

To the north of the site, there are four residences (750 feet to the northwest of the EPLC site). Further to the northeast in Old Bridge are other residential areas, as depicted in Figure 1-1. The surrounding area also consists of undeveloped wetland areas.

¹ Aquifer yield is defined as the maximum rate of withdrawal that can be sustained by an aquifer without causing an unacceptable decline in the hydraulic head in the aquifer (Freeze and Cherry 1979). Although saltwater intrusion has not been reported from upcoming (i.e., upward movement of saltwater through a confining layer) of saltwater in the Farrington Aquifer through the Woodbridge Clay, this mechanism has not been extensively investigated in the area, and therefore, may occur (Personal Communication, Ham Pucci, USGS 1989).

1.3.4.2 Populations

The closest major population centers to the CPS/Madison site are the East Spotswood/South Old Bridge in the Old Bridge Township (population 51,000), approximately 3 miles to the southwest; Sayreville (population 32,300), approximately 2 miles to the northwest; South River (population 14,300), approximately 2 miles to the west; and East Brunswick (population 37,700), approximately 3 miles to the southwest.

Groundwater

The city of Perth Amboy and Sayreville both have public water supply well fields in close proximity to the CPS/Madison site. These consist of supply wells and groundwater recharge ponds less than 1 mile from the site (see Figure 1-1). The city of Perth Amboy owns a 1,200-acre tract of land known as the Runyon watershed. The majority of Perth Amboy's potable water taps the Old Bridge Sand near the southern end of Tennent (Runyon) Pond. The Perth Amboy well field (see Figure 1-1) currently consists of four wells screened in the Old Bridge Sand at 78 to 82 feet and yielding 0.72 to 1.44 mgd. These wells were supplemented by a suction system consisting of 40 vacuum wells, which yield 0.1 mgd, and are screened at depths of 45 to 60 feet. The vacuum wells, as of October 1987, are not in operation. The total well field serves 55,000 people in Perth Amboy and South Amboy.

Sayreville Boro Water Department owns public supply wells approximately .25 miles northwest of the site, which also tap the Old Bridge Sand. Groundwater flow is in the southwest direction--in the direction of the Perth Amboy wells, and ~~not the Sayreville wells.~~

confirm in design

Alternate drinking water sources can be obtained by tapping the Farrington Aquifer (below the Woodbridge Aquifer) or by buying water from the Middlesex County Utilities Authority. Alternate sources of drinking water from surface waters have not been identified.

Surface Waters

Pricketts Brook flows through the CPS/Madison properties and discharges into Pricketts Pond. In the early 1970s, Pricketts Brook was relocated around the perimeter of the CPS/Madison plant. Pricketts Pond was excavated in 1973 as a recharge basin to supplement aquifer recharge by Tennent Pond.

Pricketts Brook continues to flow west into Tennent Pond. Tennent Pond (southwest of the site) serves to recharge shallow infiltration wells operated by Perth Amboy Water Works. Tennent Brook then flows northwest and joins the South River, at which point the South River flows north to the Raritan River, a distance of 4.5 miles. Sayreville pumps water from the South River to two recharge ponds (northwest of the site) and infiltration wells.

NJDEP does not have a water quality monitoring station on Tennent Brook; therefore, current water quality information is not available for the waters closest to the site. The NJ 1982 State Water Quality Inventory Report (NJDEP 1983) did provide the information needed to describe the South River watershed. The South River watershed (from the headwaters to the intake of the Sayreville Water Department) and Tennent Brook (above Tennent Pond dam) are classified by the State of New Jersey Water laws as FW-2 Nontrout waters. The designation of FW-2 denotes fresh water that is not within Federal, State, park, forest, or fish and wildlife lands that must be maintained in their natural state

What are water quality standards for this?

of quality, or that are subject to manmade wastewater discharges. Nontrout waters are generally not suitable for trout because of their physical, chemical, or biological characteristics, but are suitable for a wide variety of other species. Designated uses of FW-2 Nontrout waters are as follows: public water supply (after treatment); maintenance, migration, and propagation of natural and established biota; primary contact recreation; industrial and agricultural water supply; and other reasonable uses.

Waters downstream of the FW-2 Nontrout waters have the following designated uses: shellfish harvesting (where permitted); maintenance, migration, and propagation of natural and established biota; primary contact recreation; industrial and agricultural water supply; and other reasonable uses. The actual uses, as opposed to the designated uses, have not been provided.

The surface waters are not used directly as drinking water sources. Recreational use of the Runyon watershed is not permitted. The area is, however, accessible by foot and potential recreational use or access exists since residential homes are nearby. Information on the Pricketts Brook watershed was not available.

1.3.5 Ecology

The CPS/Madison site is surrounded by areas of wetlands that are considered sensitive environments (OSWER Directive 9355.3-01). The USGS has designated a portion of the CPS property to be within wetland areas. Figure 1-15 outlines the wetland portions surrounding the CPS/Madison site.

The surface water drains through Pricketts Brook to Pricketts Pond and then northwest by way of Tennent Pond and Brook. The closest wetlands to the site surround Pricketts Brook



FIGURE 1-15. WETLAND AREAS SURROUNDING THE CPS/MADISON SITE

and Tennent Brook and are affected by surface-water drainage potentially carrying contaminants (see Figure 1-15).

These ecologically sensitive areas have not been investigated to date. The fauna and flora that are supported by these wetlands should be identified as well as the presence of any endangered species. Also, species that are consumed by humans or in other ways directly related to the human food chain should be identified in order to accurately assess the threat to human health.

The site investigation report (August 1982) only mentions that, "trees and shrubs adjacent to the site were dead and dying." Species or other specifics were not identified.

1.4 NATURE AND EXTENT OF GROUNDWATER CONTAMINATION

Table 1-9 presents the maximum contaminant concentrations detected in groundwater throughout the history of the CPS/Madison site (based on available information). Appendix A.10 presents for each well the range in concentration of each contaminant monitored. Appendix A.10 also provides dates for which the maximum and minimum contaminant concentrations were reported. Of the metals, zinc has been detected at the greatest concentrations. Of the organic contaminants, methylene chloride has been detected at the greatest concentrations. These data suggest that zinc and methylene chloride are probably the inorganic and organic contaminants that were released in the greatest amounts or concentrations.

The CPS/Madison site may be directly influenced by the Evor Phillips Superfund site located upgradient (see Figure 1-1). A comprehensive investigation of the connection between the CPS/Madison and Evor Phillips sites has not been conducted,

delete

1/10/82
9/10/82
9/10/82
9/10/82

TABLE 1-9. MAXIMUM CONTAMINANT CONCENTRATIONS REPORTED IN GROUNDWATER

Constituent	Maximum Concentration (ppb)	Well in Which Maximum Concentration Was Detected
Zinc	1,660,000	M-2
Lead	18,400	E
Cadmium	2010	M-2
Copper	53,600	No.12
Methylene chloride	391,000	B
1,1,2,2-tetrachloroethane	8430	S-1
1,2-dichloroethane	4200	No.12
1,1-dichloroethane	640	A
1,1-dichloroethene	6	WCC-15S
Carbon tetrachloride	4480	WCC-6S
Bromoform	2600	No.12
Benzene	655	No.12
Toluene	3000	WCC-12
bis(2-ethylhexyl)phthalate	175	WCC-11S
1,2-dichloropropane	375	No.12
Chlorobenzene	1100	WCC-12
trans-1,2-dichloroethylene	1600	WCC-12
Ethylbenzene	330	No.12
Total Xylenes	1190	No.12
1,1,1-trichloroethane	2200	WCC-6S
Trichloroethylene	1230	No.12

TABLE 1-9. MAXIMUM CONTAMINANT CONCENTRATIONS REPORTED IN GROUNDWATER
(Continued)

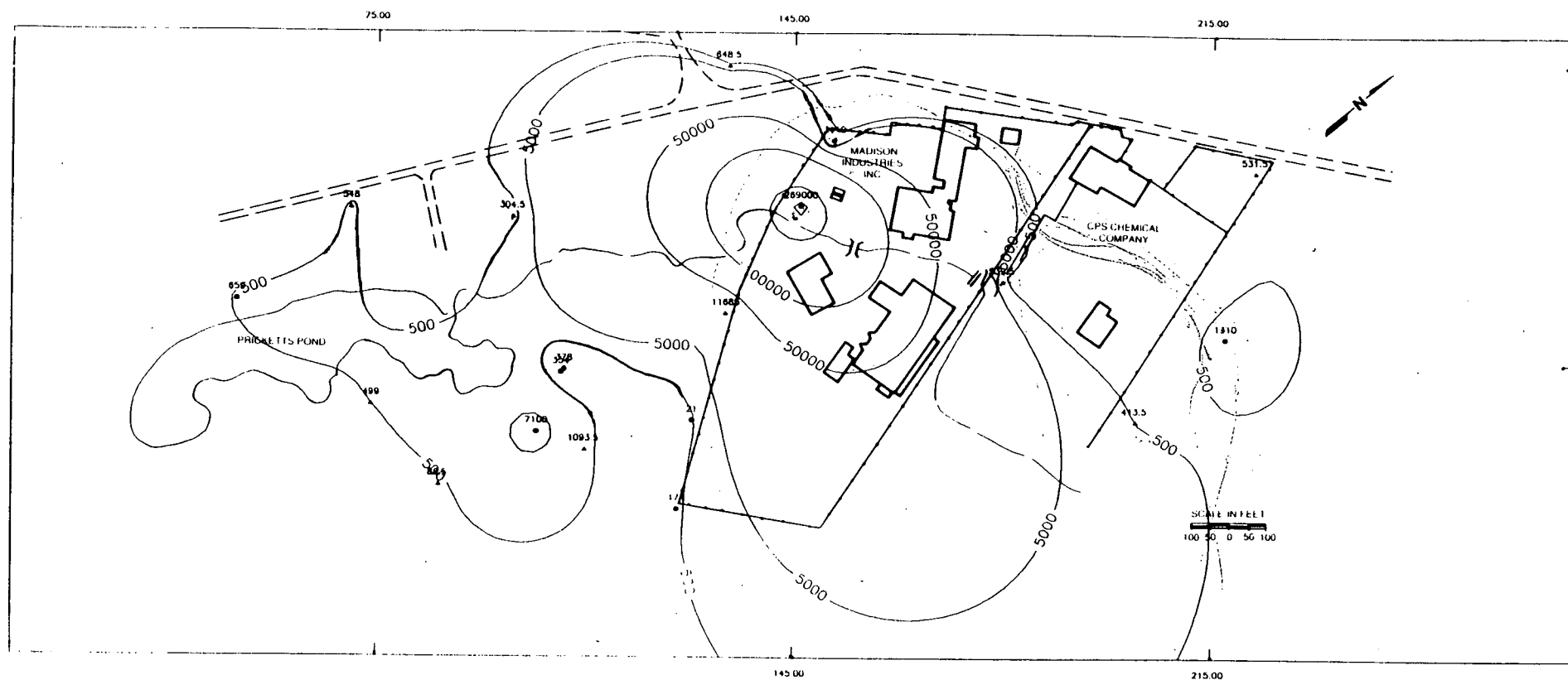
Constituent	Maximum Concentration (ppb)	Well in Which Maximum Concentration Was Detected
Chrysene	24	M-1, WCC-6S
1,3-dichlorobenzene	21	WCC-6S
1,4-dichlorobenzene	21	WCC-6S
Hexachlorobenzene	182	No.12
N-nitrosodiphenylamine	471	WCC-6S
Benzidene	34	WCC-9D
Dimethylphthalate	93	WCC-11S
bis(2-chloroethoxy)methane	41	No.12
Naphthalene	41	No.12
Nitrobenzene	182	No.12
N-nitroso-di-N-propylamine	182	No.12
2-chloronaphthalene	102	No.12
Chloroform	1070	WCC-6S
Acenaphthene	23	WCC-6S
Acenaphthylene	46	WCC-6S
Hexachlorocyclopentadiene	184	WCC-6S
Vinyl chloride	11	DW-7S
Chloromethane	9	WCC-15M
Trichlorofluoromethane	3	PA-05
1,2-dichloroethene	1600	WCC-15S
Tetrachloroethene	24	DW-7S
1,3-dichloropropene	6	B

although some of the suspected contaminants (e.g., zinc, lead, cadmium, copper, and organics) are the same at both sites. The following evaluation of the nature and extent of contamination at the CPS/Madison site does not consider the potential impacts of the Evor Phillips site since adequate information to evaluate or quantify such impacts does not exist.

In order to evaluate the extent of contamination, isoconcentration maps were constructed for zinc, lead, cadmium, and total VOCs, as measured in 1988 by Wehran (1989). (Refer to Appendix A.4 and A.5 for a complete summary of analytical results for groundwater samples.) The 1988 data are the most recent data available and consequently, represent the best available estimate of the current extent of the contaminant plumes. TVOCs, rather than individual organic constituents, were contoured because data for any one organic contaminant did not adequately characterize the extent of migration of all organic contaminants released.

The concentrations detected in deep and shallow wells were not contoured separately. When two or more concentrations were detected for a well cluster, concentrations were averaged and contoured for the cluster location (non-detects were averaged as zeroes). Contours representing the New Jersey Drinking Water Standards are shown on the maps for lead and cadmium. The drinking water standard for lead is 50 ppb, and the standard for cadmium is 3.7 ppb. The Federal ambient water quality standard was plotted as 5,000 ppb on the zinc isoconcentration map.

Figure 1-16a presents contours of 1988 zinc concentrations. The map shows that the highest known concentration of zinc (269,000 ppb) occurs at well M-2, located south of Madison Industries' pumping well MI-T1. Concentrations of zinc generally decrease radially away from well M-2, except in the south and



LEGEND:

- Well
- Well Cluster

— 100 — Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-16a. 1988 ZINC CONCENTRATIONS (ppb)

southwestern directions. The "non-radial" shape of the zinc plume in the south and south-western directions indicates that Pricketts Brook and/or Pricketts Pond may be involved in determining the extent of zinc contamination. Although the contours do not radiate or extend immediately downgradient from the boundaries of Pricketts Brook and Pricketts Pond (a zinc "high" is located southeast of the upper portion of Pricketts Pond), the data suggest Pricketts Pond as a potential, continuing source of contamination.

Pond
controlling
plume
should
be
deleted.
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The map illustrates that the wells sampled in 1988 were not adequate to define the extent of the zinc plume. Specifically, zinc concentrations in groundwater do not appear to decrease to a background concentration. A zinc concentration was detected in groundwater however, southwest of the site, the minimum concentrations are approximately 500 ppb. Further investigations should include the monitoring of wells farther away from the site in order to confirm that greater concentrations of zinc have not migrated downgradient.

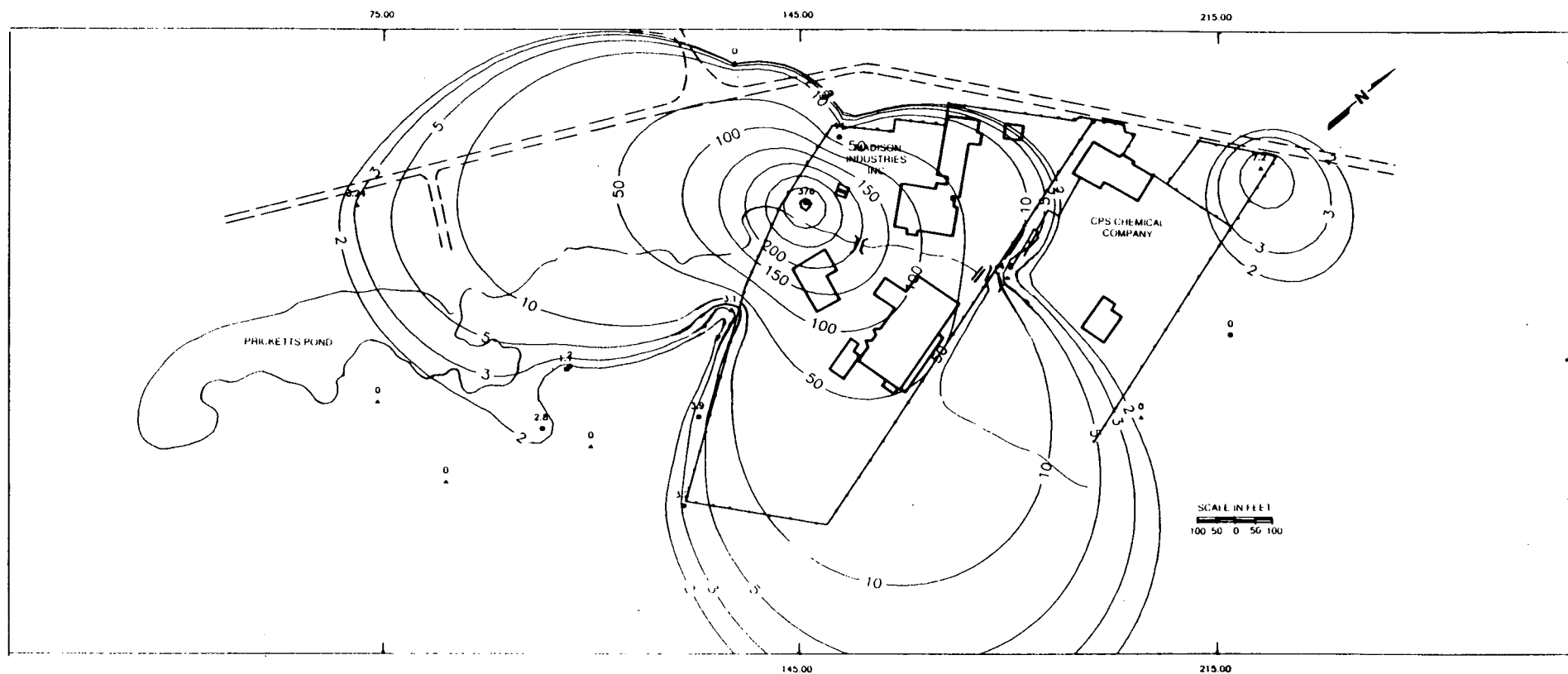
Wehran (1989) concluded from the 1988 data that active withdrawal from MI-T1 accounts for the containment of much of the zinc plume on the Madison property. The concentration of zinc detected in samples from well M-6, located next to MI-T1, is 3,410 ppb. The Federal ambient water quality standard for zinc is 5,000 ppb. With respect to water quality, the extent of the zinc plume is approximately the area bounded by the 5,000-ppb contour. The extent of the 5,000-ppb contour has not been defined adequately in the southeastern direction.

delete

Not shown on the contour map is the vertical extent of the zinc plume. In 1988, the deepest detected concentration of zinc was 403 ppb, detected in well WCC-3D, which extends to a depth of 85.05 feet (-55.57 feet relative to MSL). The concentration of

Don't
define
Federal
background
level

zinc detected in the middle well of the WCC-3 well cluster, well WCC-3M, was 424 ppb, essentially the same as that detected in the deeper well. Well WCC-3M extends to a depth of 50.76 feet (-22.37 feet relative to MSL). Zinc has been detected at a concentration of 25 ppb in Layne well number 2, which is screened in the Farrington Sand. Typically, the highest zinc concentration was reported for the shallower well of the well clusters. As Wehran (1989) notes, "Large concentration differences between shallow and deep monitoring well installations were also observed for zinc at a number of [well] installations. A tendency for higher concentrations in the shallow portions of the aquifer relative to the deeper regions was noted, especially at the newly installed DW series well couplet locations." Concentrations of zinc that exceed the Federal ambient water quality standard (5,000 ppb) were detected to a depth of 51.88 feet (-28.63 feet relative to MSL, well 11-M, 16,400 ppb). Figure 1-16b presents contours of the 1988 lead concentrations. The map shows a pattern of concentration remarkably similar to that of zinc, although the pattern may be more influenced by the geometry of the well field rather than factors influencing the contaminant migration. Like zinc, the highest lead concentration occurs at well M-2. The second highest concentration of lead occurs at well M-6, next to Madison Industries' pumping well MI-T1. The data indicate that the extent of lead contamination has been fairly well defined, although additional testing would be required both to confirm the 1988 data and to investigate the possibility that contaminants have migrated to locations further downgradient. As with all of the 1988 data, informational deficiencies exist that prohibit determining the southeastern extent of contamination. The 50-ppb contour indicates the zone of contamination that exceeds New Jersey state drinking water standards.



LEGEND:

- Well
- ▲ Well Cluster

— 100 — Concentration Contour, ppb

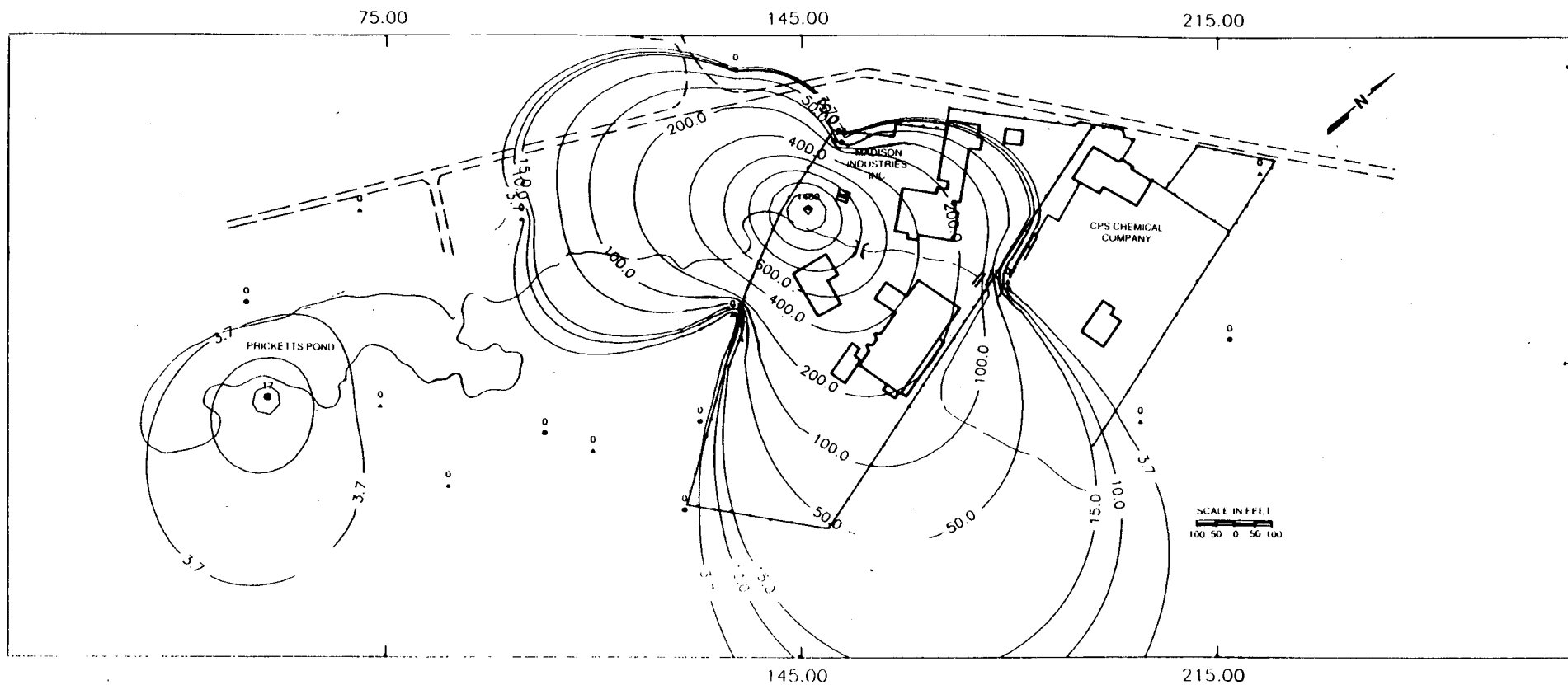
Note: All locations are approximate.

FIGURE 1-16b. 1988 LEAD CONCENTRATIONS (ppb)

In 1988 the deepest detected concentration of lead was 3 ppb in well WCC-3D, which extends to a depth of 85.05 feet (-55.57 feet relative to MSL). This concentration is well below the drinking water standard for lead (50 ppb). The concentration of lead detected in the middle well of the WCC-3 well cluster, well WCC-3M, was less than 0.91 ppb, a concentration less than that detected in the deeper well. Well WCC-3M extends to a depth of 50.76 feet (-22.37 feet relative to MSL). Of the six well clusters in which lead was detected in at least one of the wells, the highest lead concentration more often occurred in the deeper well of the cluster. Well M-2, which contained the only concentration of lead greater than the drinking water standard, is 37.9 feet deep (-14.22 feet relative to MSL).

Figure 1-16c presents contours of the 1988 cadmium concentrations. The cadmium map, similar to those of lead and zinc, depicts the highest concentration (1,480 ppb cadmium) at well M-2. Well M-6, located next to pumping well MI-T1, contained the second highest concentration of cadmium. A second zone of concentration, which was not obvious with zinc and lead, occurs at the southwestern extent of Pricketts Pond. This zone is defined by only one well, where a cadmium concentration of 17 ppb was detected. Otherwise, the extent of cadmium contamination appears fairly well defined, except in the southeastern direction.

The cadmium and zinc isoconcentration maps indicate that (1) Pricketts Pond may be associated with a preferential pathway of contaminant migration, or (2) as is more evident with the cadmium data, Pricketts Pond may act or may have acted as a contaminant source (in addition to the original contaminant source(s) on the Madison site itself).



LEGEND:

- Well
- Well Cluster

--- 100 --- Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-16c. 1988 CADMIUM CONCENTRATIONS (ppb)

*Don't go to get
this info only*

Rephrase

map
p.

Not illustrated on the contour map is the vertical extent of the cadmium plume. Cadmium was detected in only three of the wells monitored in 1988. The deepest of these wells are M-2, which extends to a depth of 37.9 feet (-14.22 feet above MSL) and M-6, which extends to a depth of 48.7 feet (no reference elevation has been provided for well M-6). Cadmium was not detected at any of the well cluster locations in 1988.

Let's explain it shall we.

Figure 1-16d presents contours of the 1988 TVOC concentrations. Not surprisingly, the pattern of volatile organic compounds (VOC) contamination does not correspond to that of the metals. The highest TVOC concentration occurs at the southeastern corner of the Madison Industries property, with concentrations decreasing slightly cross-gradient towards the northeastern portion of Pricketts Pond. Another zone of high concentration occurs near well MI-T1, which has probably resulted from active withdrawal from well MI-T1. Nondetectable concentrations of VOCs appear to delineate the extent of the VOC plume. As recommended previously, however, additional sampling should be performed both for data verification and to ensure that the downgradient extent of VOC contamination has been detected.

Wehran (1989) reports that "large concentration differences were observed vertically at the DEP well cluster location east of Pricketts Pond. Here the concentration of total volatiles was several orders of magnitude greater in the well screened at the shallow location (DEP-2) within the aquifer relative to an adjacent DEP well (DEP-1) completed at a deeper depth. A similar finding was observed during the 1987 sampling round."

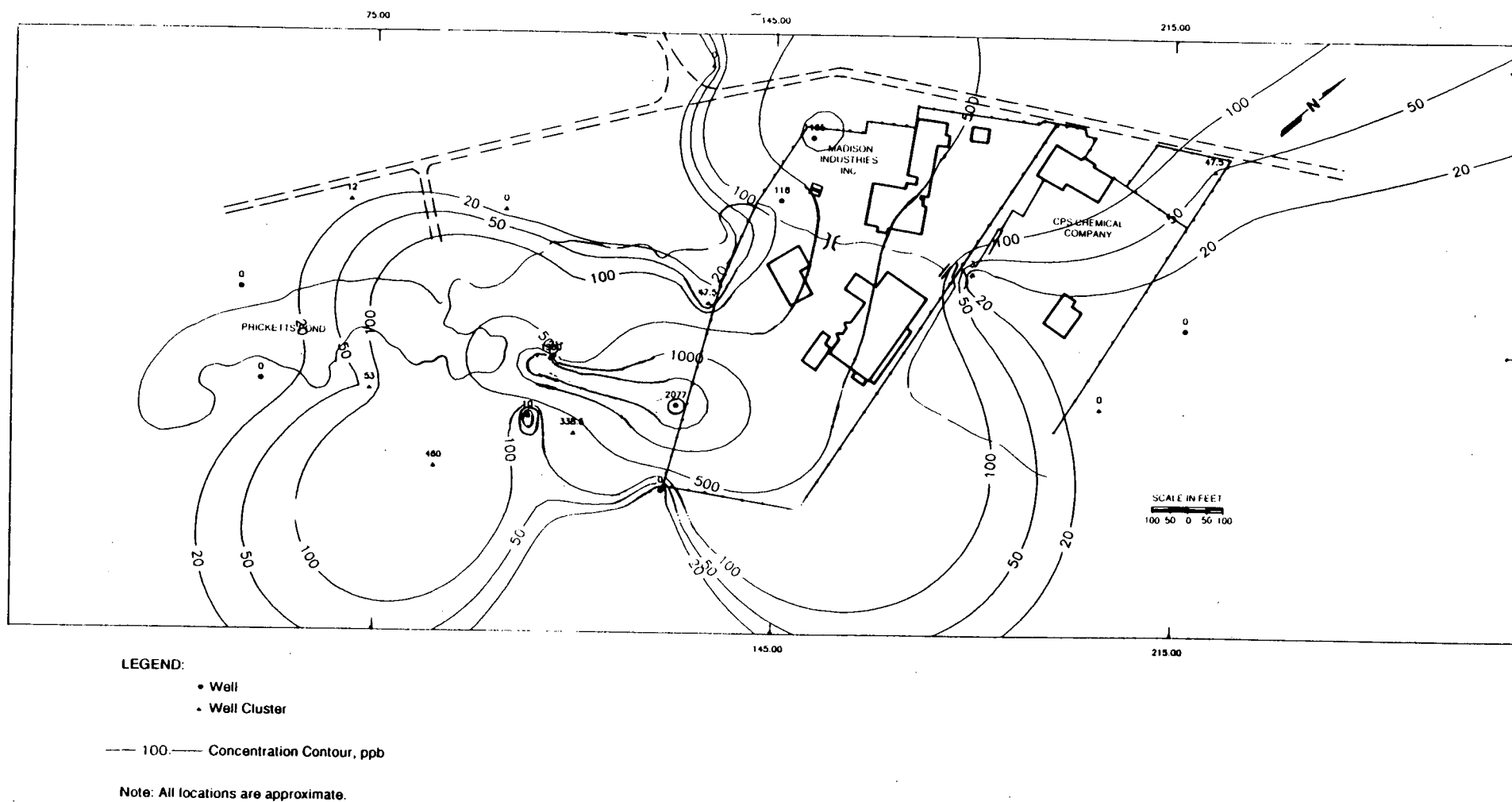


FIGURE 1-16d. 1988 TVOC CONCENTRATIONS (ppb)

1.5 CONTAMINANT FATE AND TRANSPORT

1.5.1 Physical Controls

Based on previous investigations of the study area and site characteristics, various physical controls could have a significant impact on the fate and transport of contaminants. The major physical controls on contaminant fate and transport include (1) soil characteristics, (2) the effect of pavement, (3) surface-water and groundwater interactions, (4) geology of the Old Bridge Sand, and (5) variety of pumping/artificial recharge scenarios. Each of these physical controls is discussed in more detail in the following paragraphs.

Soils in the study area are contaminated and could be a continuous source of contamination to both surface water and groundwater. The water table is relatively shallow (0 to 5 feet BLS), which allows most of the soil profile during part of the year to be in direct contact with the saturated zone, increasing contaminant mobility. The majority of the soils in the study area are relatively permeable, which also tends to increase leachability of contaminants (i.e., decreasing adsorption effects).

The operating areas within the CPS/Madison facility were paved to inhibit surface infiltration of precipitation and/or potential contamination. The pavement's effect on the migration of contaminants in the soil beneath the pavement is not clear. Assuming that the soils were contaminated prior to paving, the pavement could serve to decrease volatilization of VOCs and to increase the amount of time required to flush leachable contaminants from the soils. Therefore, as a result of paving the area, the soils could act as a source of contamination for a longer time period.

In addition, depending on the effectiveness of the runoff catchment structures associated with the pavement (e.g., berms or ditches), the pavement could disperse contaminated runoff. Consequently, soil contamination from surface infiltration could occur outside the paved area.

Surface water may be both a contaminant source to the groundwater system and a sink for contaminants from the groundwater system, depending on whether surface water recharges the groundwater system or serves as a groundwater discharge area. Contaminated groundwater appears to be discharging to the southern reach of Pricketts Brook and the northern portion of Pricketts Pond. This is the only area of the site for which a direct correlation can be made regarding surface-water and groundwater interactions.

The contamination measured in the surface-water and sediment is possibly a combination of discharge from contaminated groundwater and of contaminated surface runoff. The fate and transport of contaminants in Pricketts Pond is unclear because little is known about Pond interaction with groundwater in the southern portion. Until the surface-water and groundwater interactions are better defined, a direct conclusion can not be made regarding the control of these interactions on the migration of contaminants.

Permeability values based on laboratory tests and pump tests indicate that the Old Bridge Aquifer is highly permeable. It is expected that high permeabilities should result in a relatively high rate of contaminant migration. It is known, however, that the Aquifer is also heterogeneous as a result of the presence of discontinuous clay layers. Heterogeneity of the Aquifer can affect the surficial pattern of recharge and discharge areas and the quantity of flow that is discharged through the system (i.e.,

it tends to decrease the rate of flow). In order to evaluate the impact of the hydrogeological parameter of the Old Bridge Aquifer on the fate and transport of contaminants, a more thorough analysis would need to be made on the Aquifer characteristics and the extent of contamination (e.g., vertical cross section of the subsurface units and the variability of contaminant concentration with depth).

From correlations between the location of pumping well M1-T1 and the extent of contaminant concentrations, it appears that the most significant physical controls on the fate and transport of contaminants are the location, number, and pumping rate of pumping wells and/or recharge wells. Adequate information on pumping wells and/or recharge wells was not available to assess the influence of all of the potential pumping scenarios that could occur on and off of the site, however.

1.5.2 The Migration and Change in the Concentration of Contaminants

In order to characterize the migration and change in the concentration of contaminants in the groundwater, the contaminant plume, measured in 1988 (Wehran), has been compared to the 1982 (NJDEP) contaminant plume. Cadmium, zinc, lead (Dames and Moore indicator chemicals), and TVOCs were used to represent the major contaminants of concern. The two data sets, 1988 and 1982, were chosen because they represent the best available and most complete sets of data on the selected parameters, well construction, sampling protocol, and the overall representation of available sampling points. The same monitoring wells were not sampled during sampling events. Consequently, an exact change in concentration between 1982 and 1988 for a given well location was not always possible to determine. Interpretations relied on the interpolation of concentrations between known data values.

The following figures are presented for each of the four indicator chemicals in order to show the change in concentration and the extent of a contaminant plume between 1982 and 1988: (1) isoconcentration maps for 1982 and 1988 data, (2) a contour map of the change in concentration between 1982 and 1988, and (3) a three-dimensional representation of the change in concentration between 1982 and 1988. The isoconcentration maps were generated as described ~~in~~ previously. The contour maps depicting the change in concentration between 1982 and 1988 were generated by subtracting the 1982 concentrations from the 1988 concentration for each node created by the grid used in generating the original isoconcentration maps. The nodal differentials of equal value represent a contour line. The three-dimensional profile of the isodifferentials is based on the same data points as the isodifferential contour maps; however, the three-dimensional profile portrays the magnitude of the change in concentration in a third dimension (z direction).

The change in the overall plume migration and concentration between 1982 and 1988 is described for each indicator chemical. The change in the number, location(s), and concentration(s) of hot spots or the highest detected concentrations are compared between 1982 and 1988. Areas of increasing and decreasing concentrations are then correlated with a known or suspected physical control on the flow patterns (i.e., migration of the contaminant). The objective is to identify the fate and transport of a contaminant based on past data in order to predict the extent and concentration of a contaminant in the future.

The procedure followed to assess the change in contamination between 1982 and 1988 did not consider the exact location and nature of the contaminant source (e.g, continuous versus non-continuous) since this information was not available. Therefore, it was assumed that the source of contamination for metals

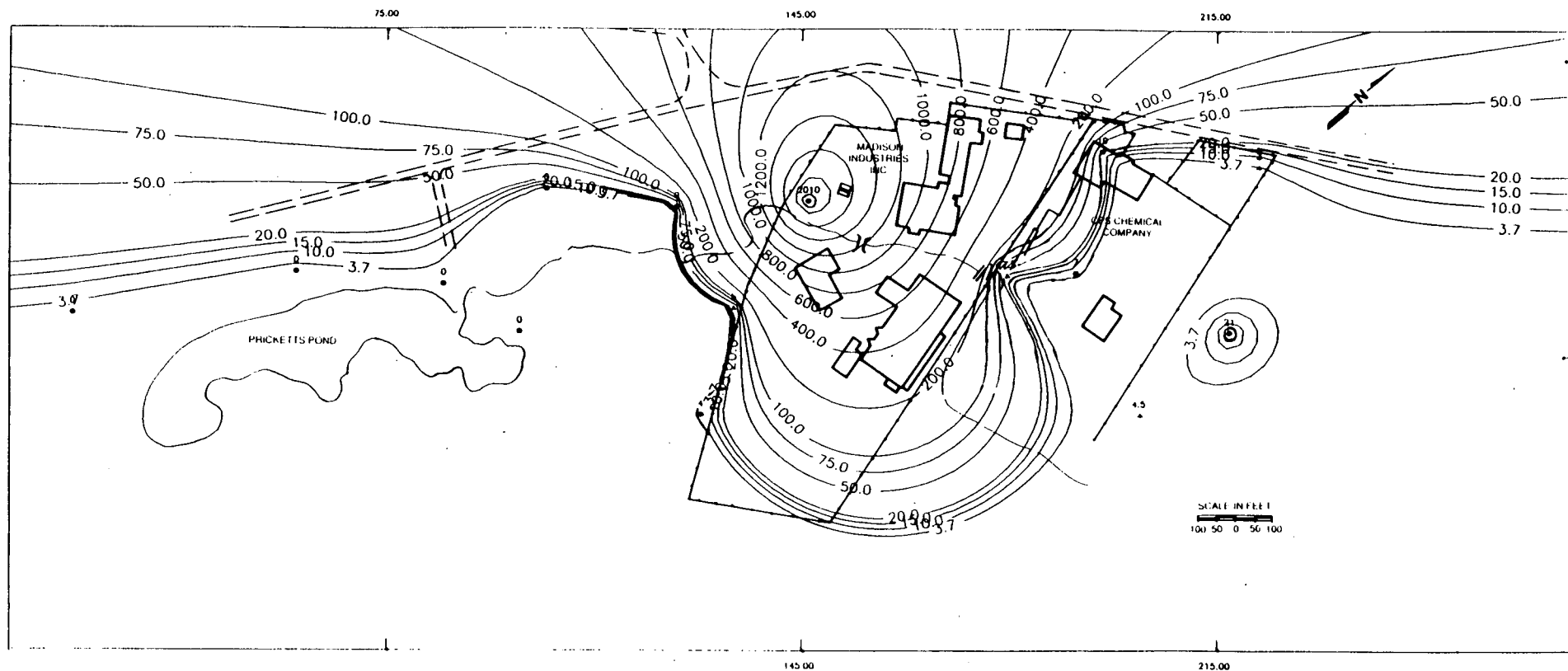
originated at the highest hydraulic gradient point on the Madison property (i.e., the uppermost northeast corner of Madison Property) and, the source of organic contamination originated from the highest hydraulic gradient point on the CPS property (i.e., the uppermost northeast corner of the CPS property). This assumption allowed for a conservative estimate of the area that could be affected downgradient of the source area.

The interpretation of the migration and extent of the contaminant plumes is limited by (1) the nature of the kriging methodology, (2) the variability in sampling locations and density between 1982 and 1988 sampling data, and (3) lack of information and data available to accurately delineate recharge and discharge areas.

1.5.2.1 Cadmium

Figures 1-17a and b present the isoconcentration maps of 1982 and 1988 data for cadmium, respectively. Relative to the 1982 cadmium plume, it appears that the 1988 cadmium plume has separated into two distinct areas of concentration, one centered over the Madison property and the other centered over the southern portion of Pricketts Pond. However, the apparent high over Pricketts Pond is based on only one data point and should be evaluated correspondingly. The total amount of cadmium present in groundwater decreased between 1982 and 1988. The location of the highest detected concentration in 1982 and 1988 is nearly identical, centered over the west side of the Madison Property. The concentration of this hot spot has decreased from 2,010 ppb in 1982 to 1,480 ppb in 1988, however.

The location of the relative change in concentration for cadmium is identifiable by correlating Figure 1-17c, a contour map of the change in concentrations, and Figure 1-17d, a three-



LEGEND:

- Well
- Well Cluster

— 100 — Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-17a. 1982 CADMIUM CONCENTRATIONS (ppb)

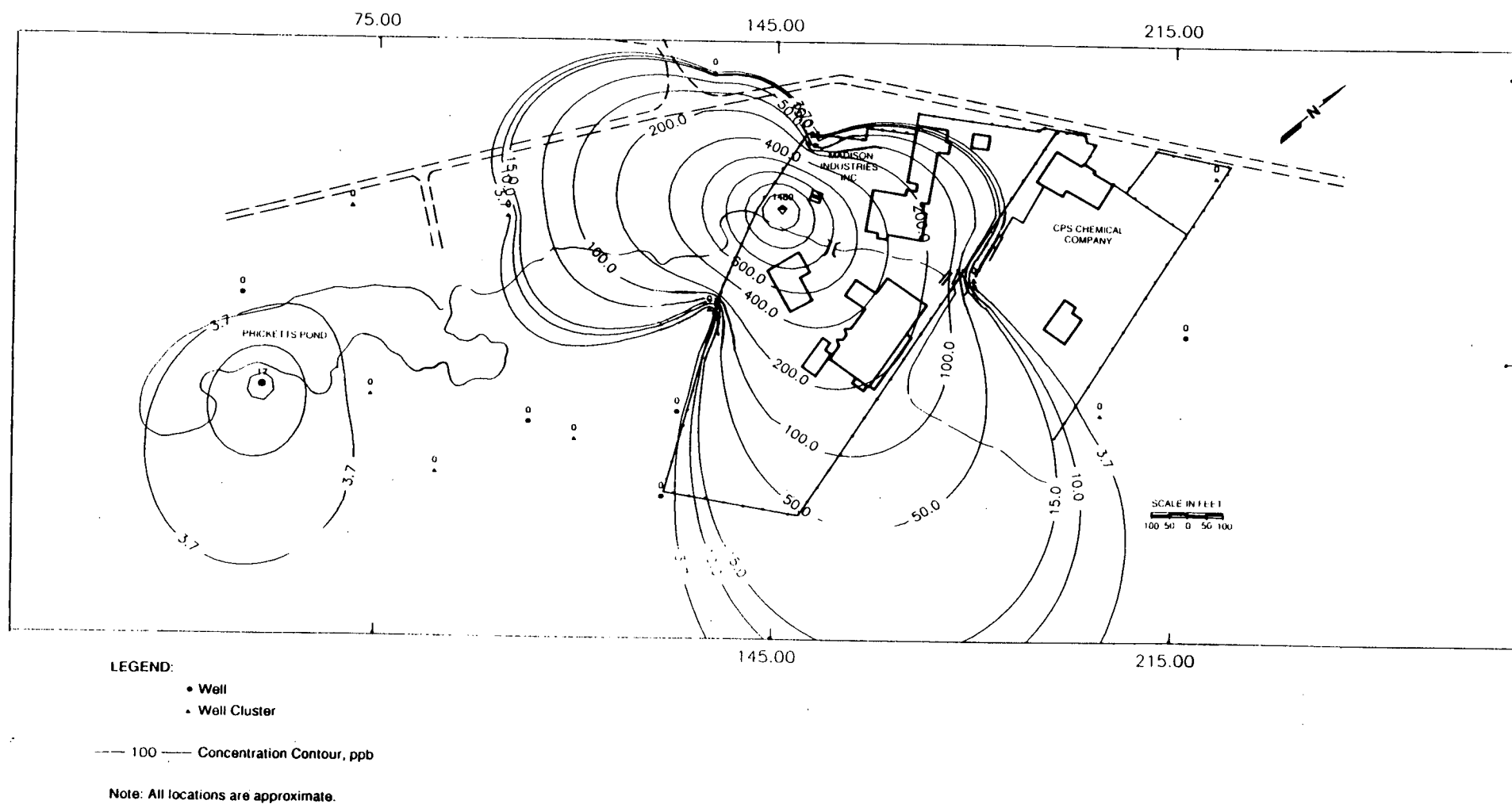


FIGURE 1-17b. 1988 CADMIUM CONCENTRATIONS (ppb)

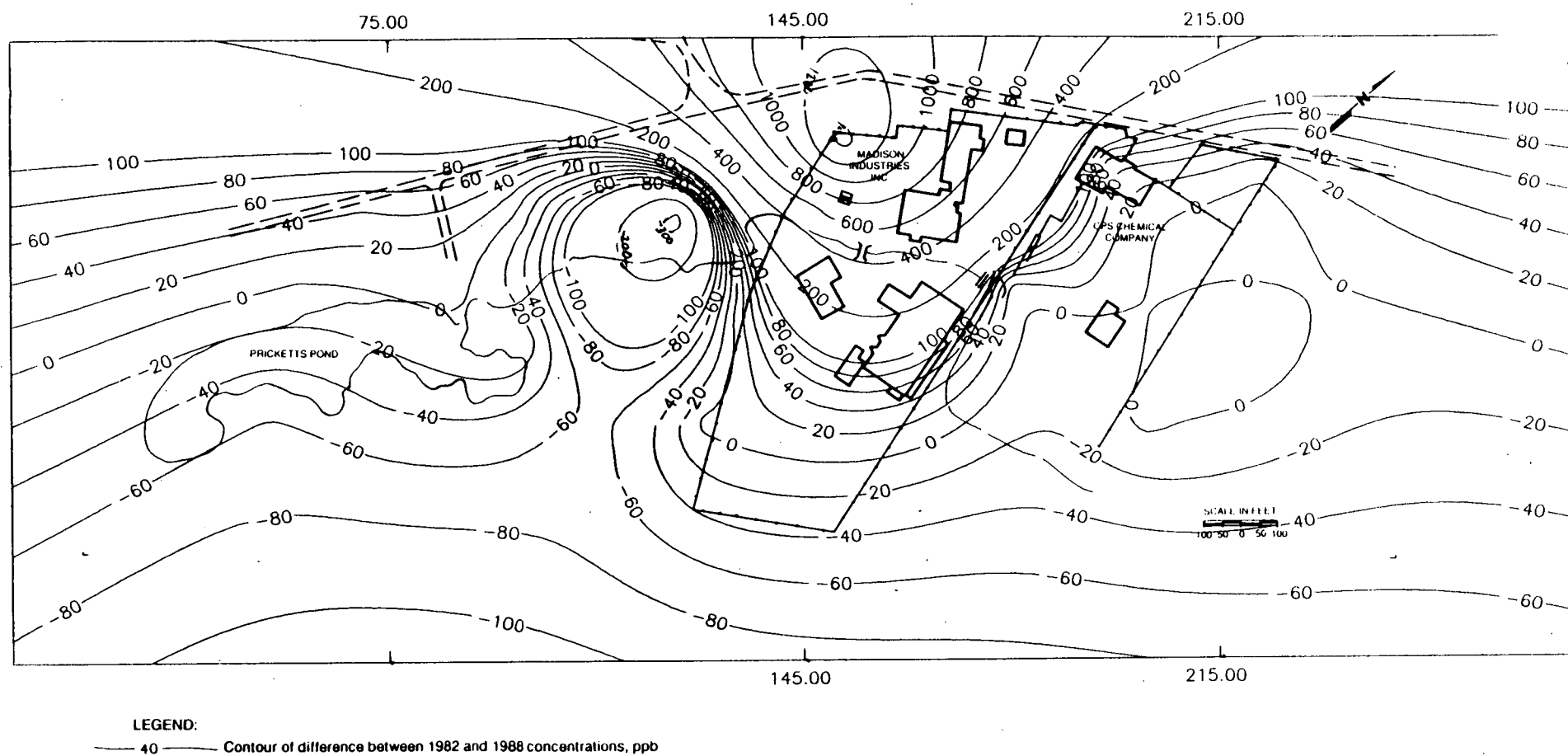


FIGURE 1-17c. DIFFERENCE BETWEEN 1982 AND 1988 CADMIUM CONCENTRATIONS

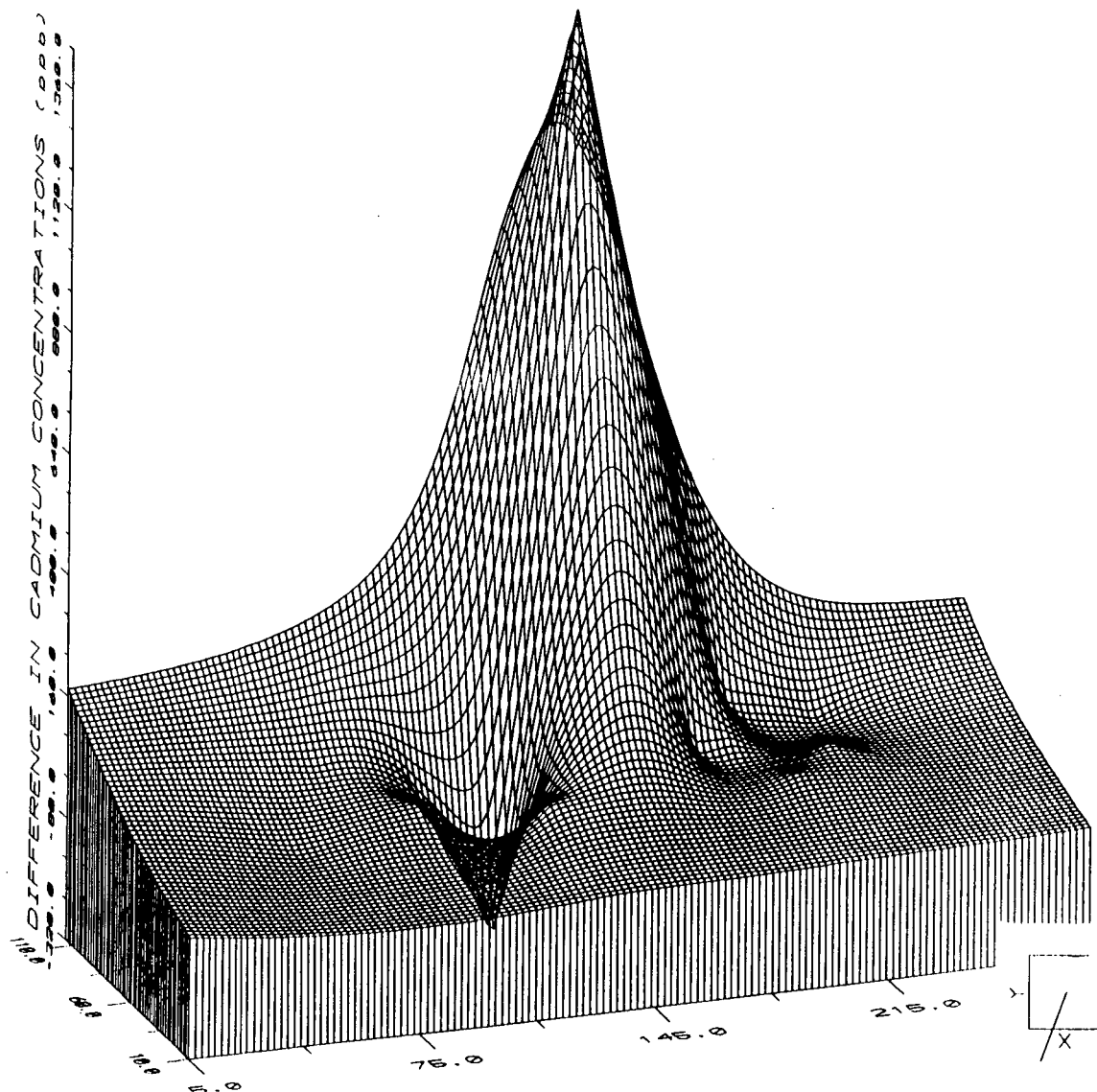
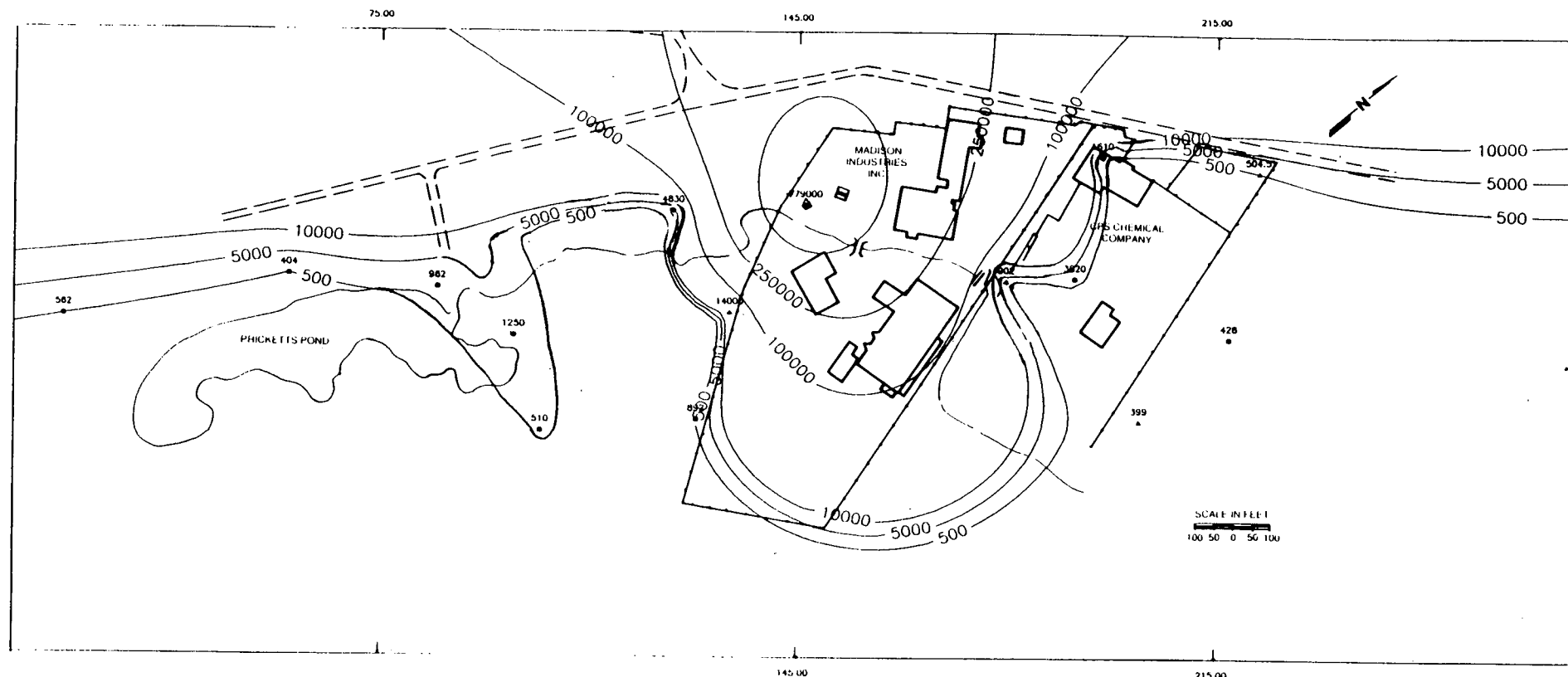


FIGURE 1-17d. 3-D PRESENTATION OF THE DIFFERENCE BETWEEN 1982 AND 1988
CADMIUM CONCENTRATIONS

dimensional portrayal of the change in concentrations. The decrease in concentrations between the hot spot of 1982 and 1988 represents a significant reduction of cadmium in this area. In addition, two areas of increasing concentration are noted--one downgradient, east of Pricketts Pond and another upgradient, east of the CPS property. The centralized reduction of the cadmium concentration corresponds to a Madison pumping well, MI-T1. The slight increase of cadmium upgradient in the vicinity of CPS property can be a result of either (1) a well that has pumped in this vicinity reversing the hydraulic gradient, (2) another source of cadmium upgradient, (3) different sampling locations between the data sets of 1982 and 1988.

1.5.2.2 Zinc

The nature of the change of the zinc plume between 1982 and 1988 is very similar to that observed in the change of cadmium concentrations (refer to Figures 1-18a through d). The overall zinc plume in 1988 is centered over the west side of the Madison property. In addition, it has migrated slightly upgradient, east of CPS relative to the zinc plume of 1982. The change in concentrations of zinc between 1982 and 1988 shows a net decrease of zinc in the system. The highest detected concentrations decreased from 779,000 ppm in 1982 to 269,060 in 1988. The majority of the concentration reduction has occurred on the west side of the Madison properties, corresponding to the location of pumping well MI-T1. The two areas of increasing concentrations (see Figure 1-18d) correspond to the same locations of increasing cadmium concentrations (i.e., areas of upward vertical gradients).



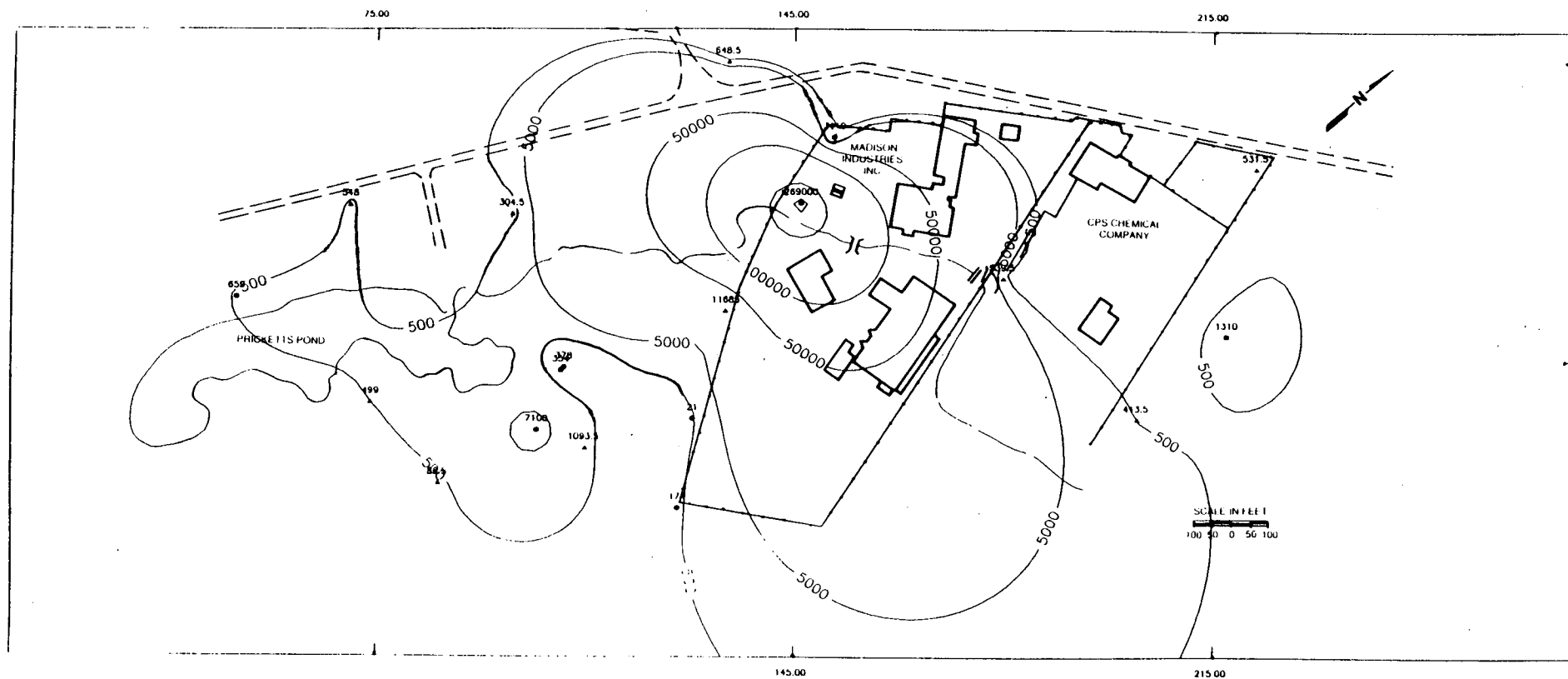
LEGEND:

- Well
- Well Cluster

— 100 — Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-18a. 1982 ZINC CONCENTRATIONS (ppb)



LEGEND:

- Well
- * Well Cluster

— 100 — Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-18b. 1988 ZINC CONCENTRATIONS (ppb)

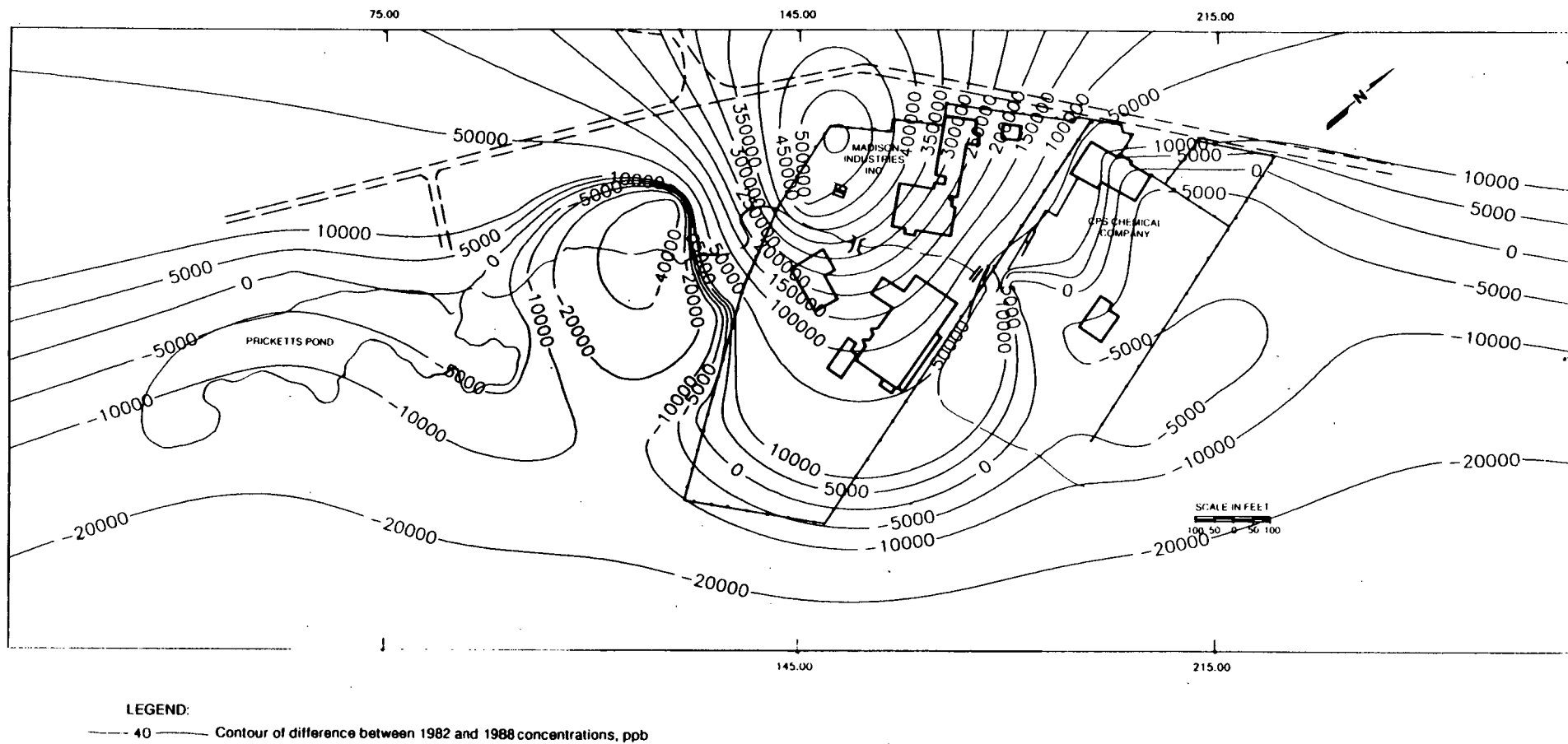


FIGURE 1-18c. DIFFERENCE BETWEEN 1982 AND 1988 ZINC CONCENTRATIONS

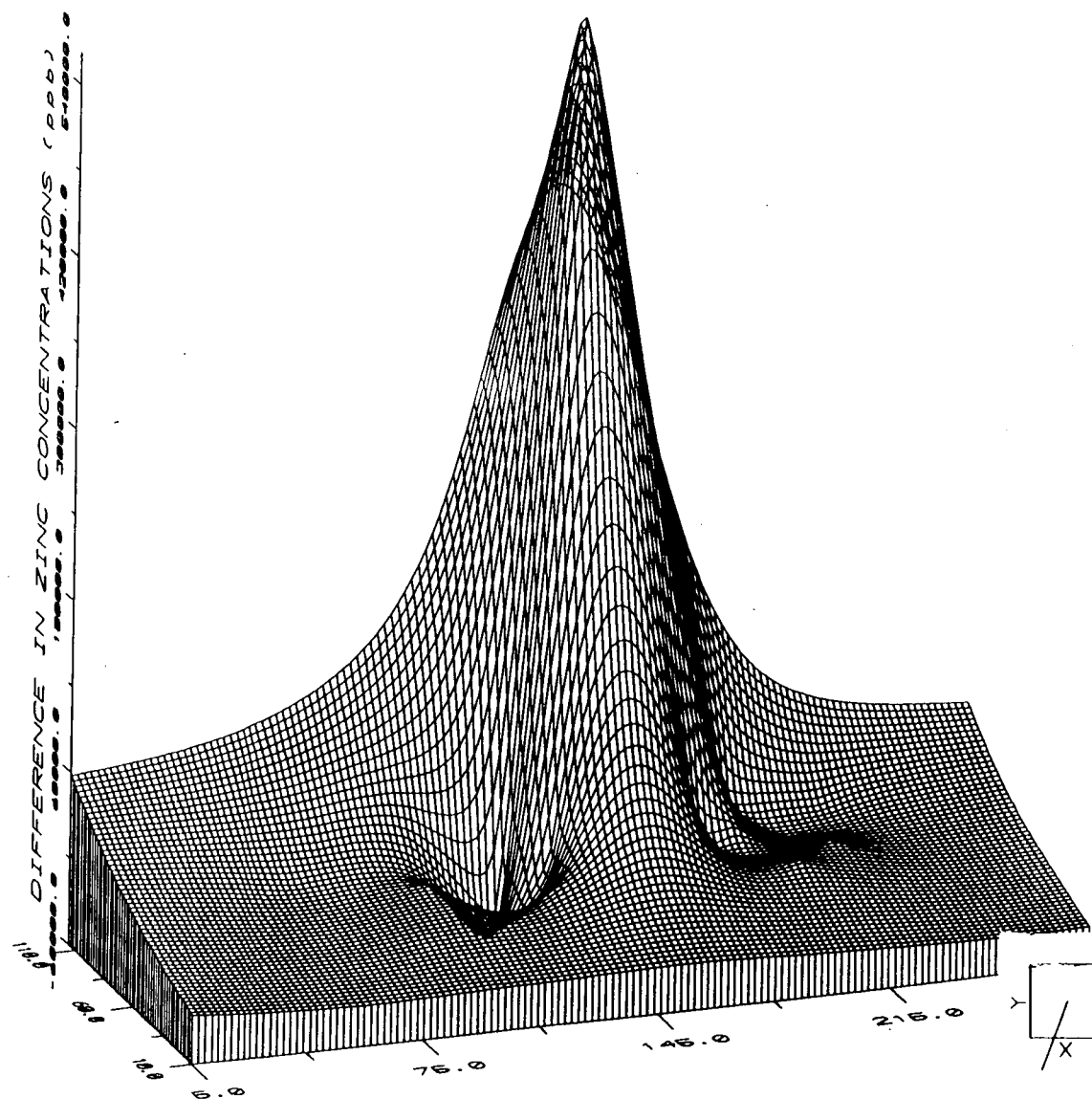


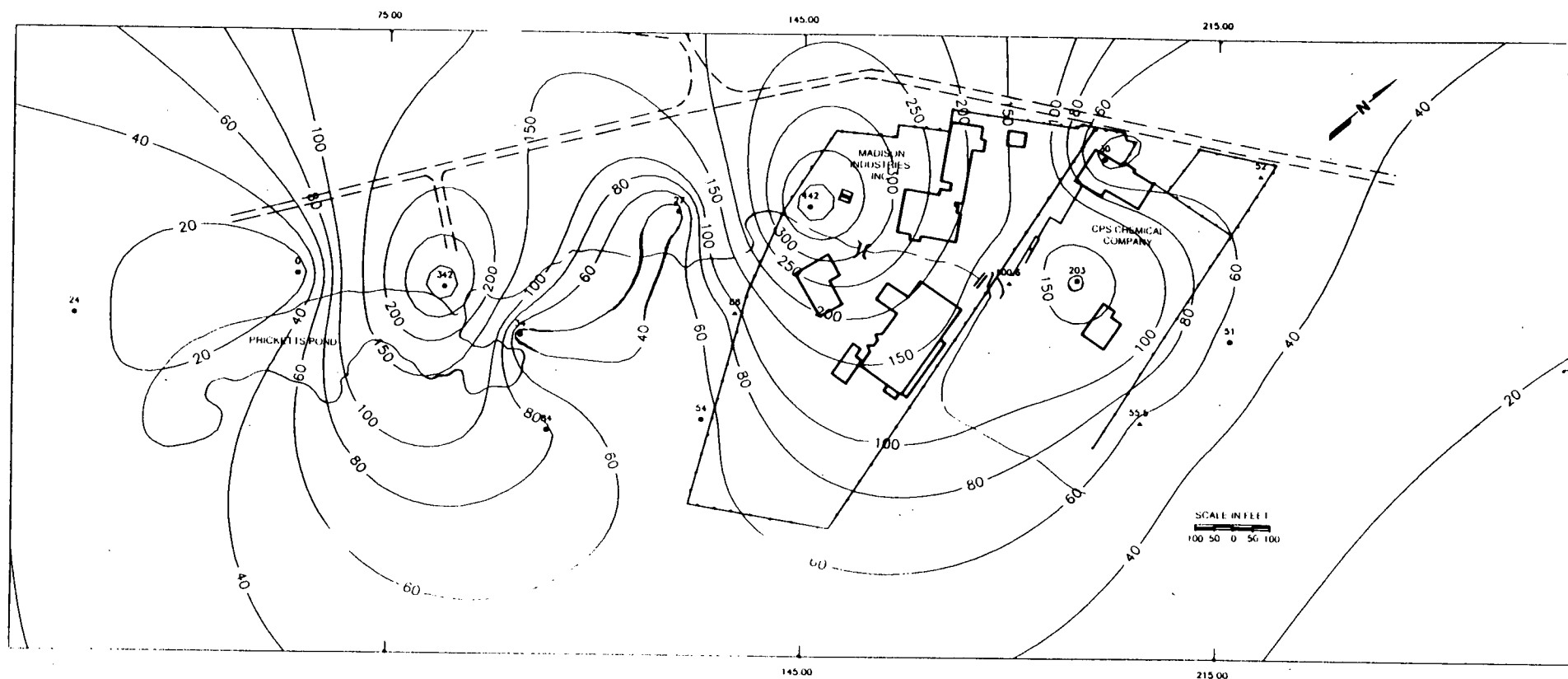
FIGURE 1-18d. 3-D PRESENTATION OF THE DIFFERENCE BETWEEN 1982 AND 1988 ZINC CONCENTRATIONS

1.5.2.3 Lead

Three areas of centralized lead concentrations are observed in the 1982 lead isoconcentration map (see Figure 1-19a)--one centered over CPS, another over Madison (northwest end), and a third centered over the north end of Pricketts Pond. These same locations are areas where, by 1988 (see Figure 1-19b), lead concentrations had been reduced, as presented in Figure 1-19c and Figure 1-19d. Relative to the lead plume of 1982, the overall lead plume of 1988 decreased in concentration and has become more centralized over the west end of Madison property. In the area where the greatest reduction of lead concentration existed, concentrations have changed from 442 ppb in 1982 to 376 ppb in 1988. Two areas of increasing lead concentration are noted in Figures 1-19c and d--one centered over the southern portion of Pricketts Pond and the other centered on the Madison property downgradient of pumping well MI-T1. As opposed to the 1988 cadmium and zinc plumes, lead appears to have been present upgradient of a source at Madison in 1982; however, it does not appear to have migrated significantly upgradient in 1988.

1.5.2.4 Total Volatile Organic Compounds

Figures 1-20a and b present the isoconcentration of the TVOC plume in 1982 and 1988, respectively. The highest concentration detected in 1982 corresponds to monitoring well S-1, which is located on the east boundary between the Madison and CPS properties. The majority of the 1982 TVOC plume expands northwest and southeast, as compared to a northeast and southwest orientation observed in the 1988 TVOC plume. Three hot spots are noted in the 1988 TVOC plume--one corresponds to pumping well MI-T1, another corresponds to monitoring well WCC-12 (downgradient from S-1 and east of Madison property boundary), and the third is centered at monitoring wells DEP 1 and 2 (eastern tip of



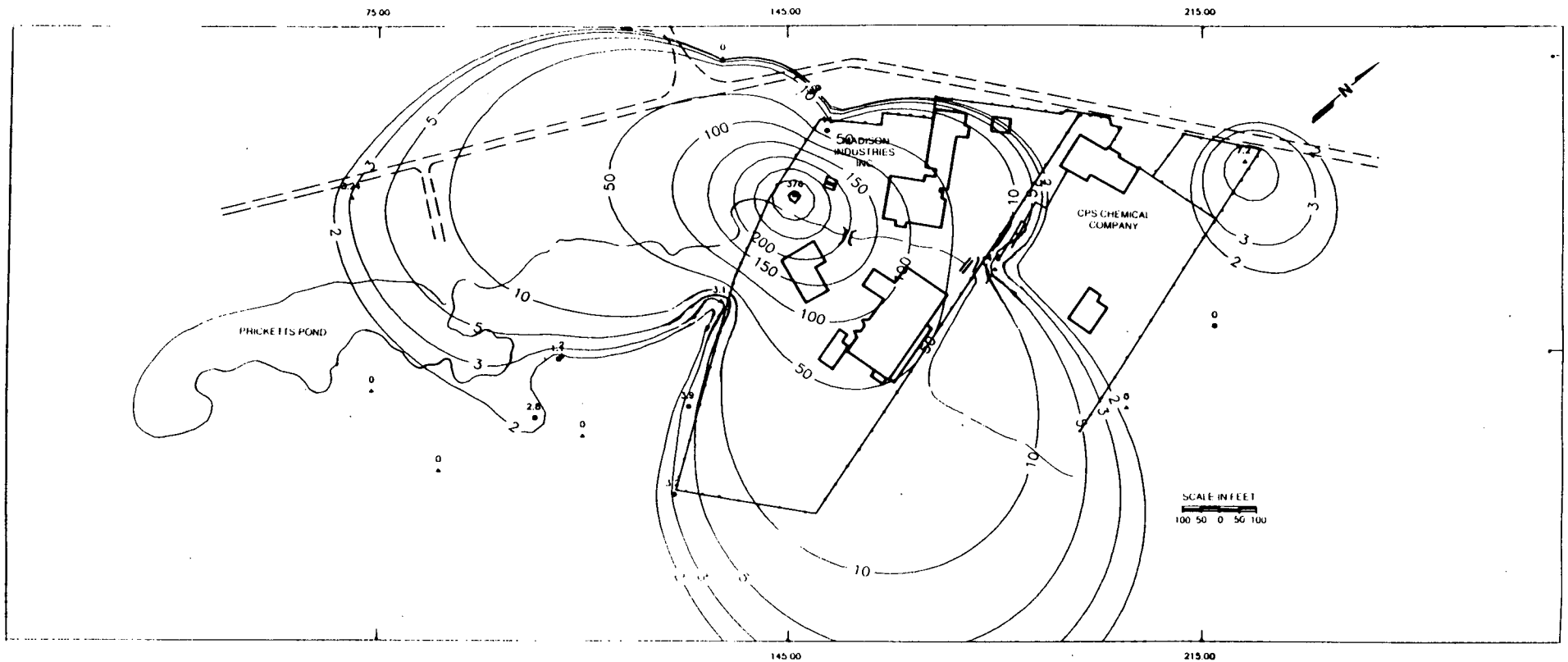
LEGEND:

- Well
- Well Cluster

— 100 — Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-19a. 1982 LEAD CONCENTRATIONS (ppb)



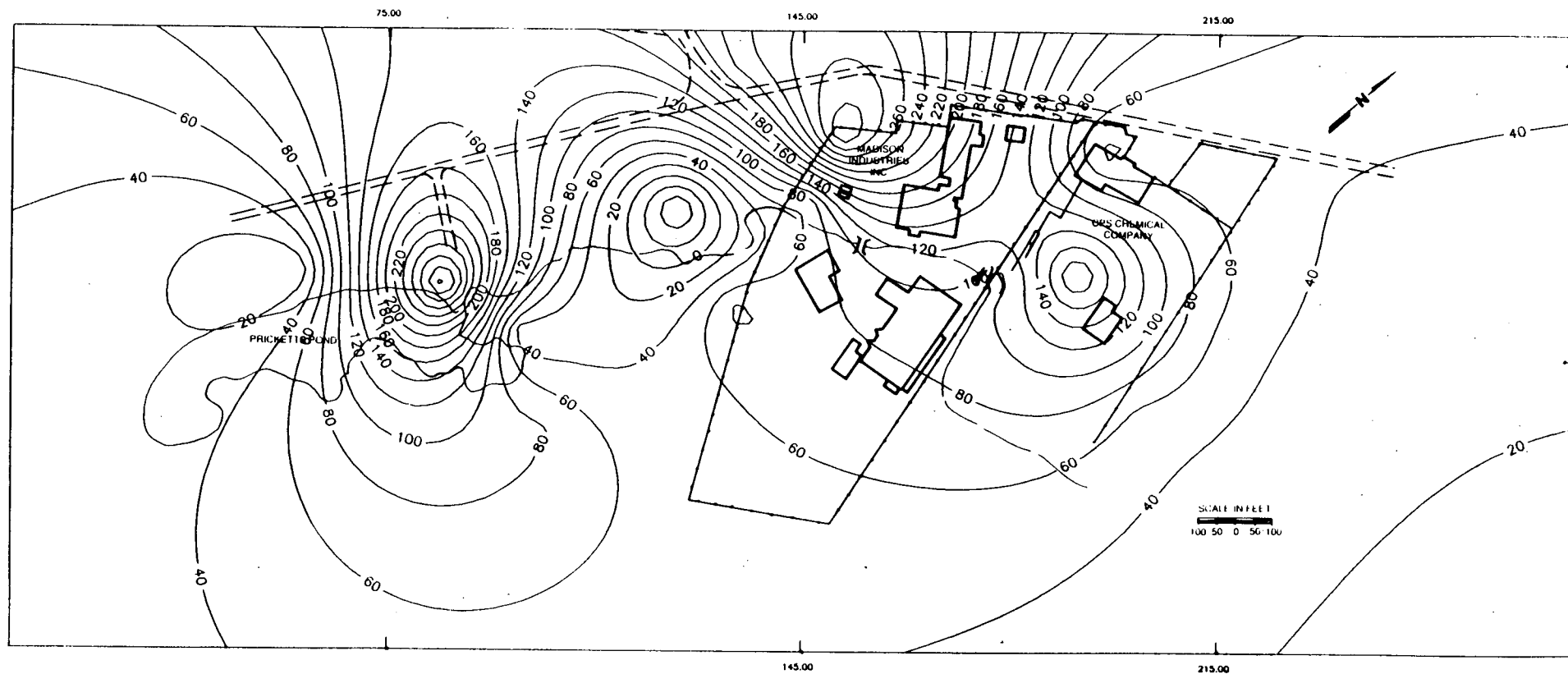
LEGEND:

- Well
- ▲ Well Cluster

— 100 — Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-19b. 1988 LEAD CONCENTRATIONS (ppb)



LEGEND:

— 40 — Contour of difference between 1982 and 1988 concentrations, ppb

FIGURE 1-19c. DIFFERENCE BETWEEN 1982 AND 1988 LEAD CONCENTRATIONS

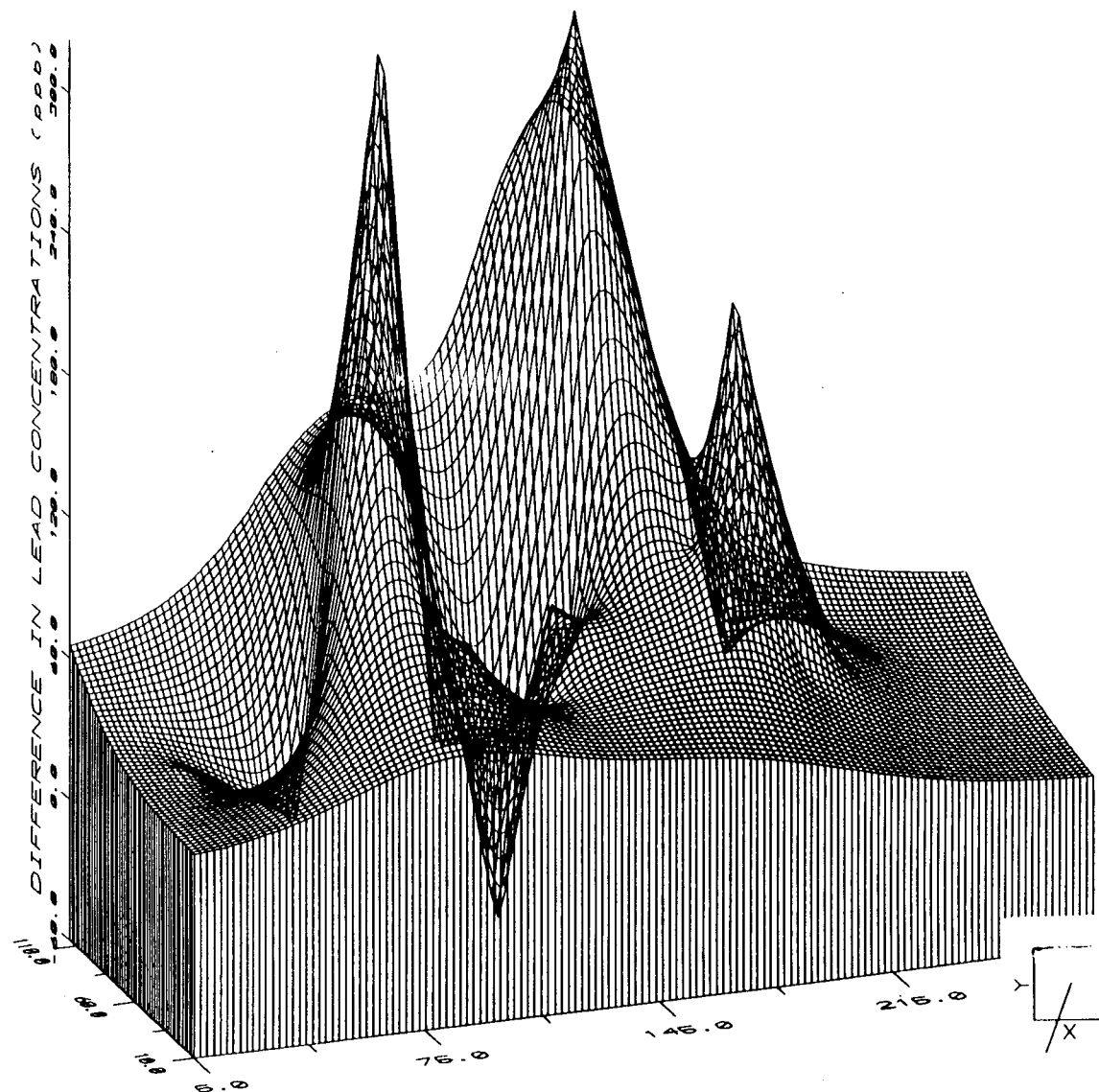
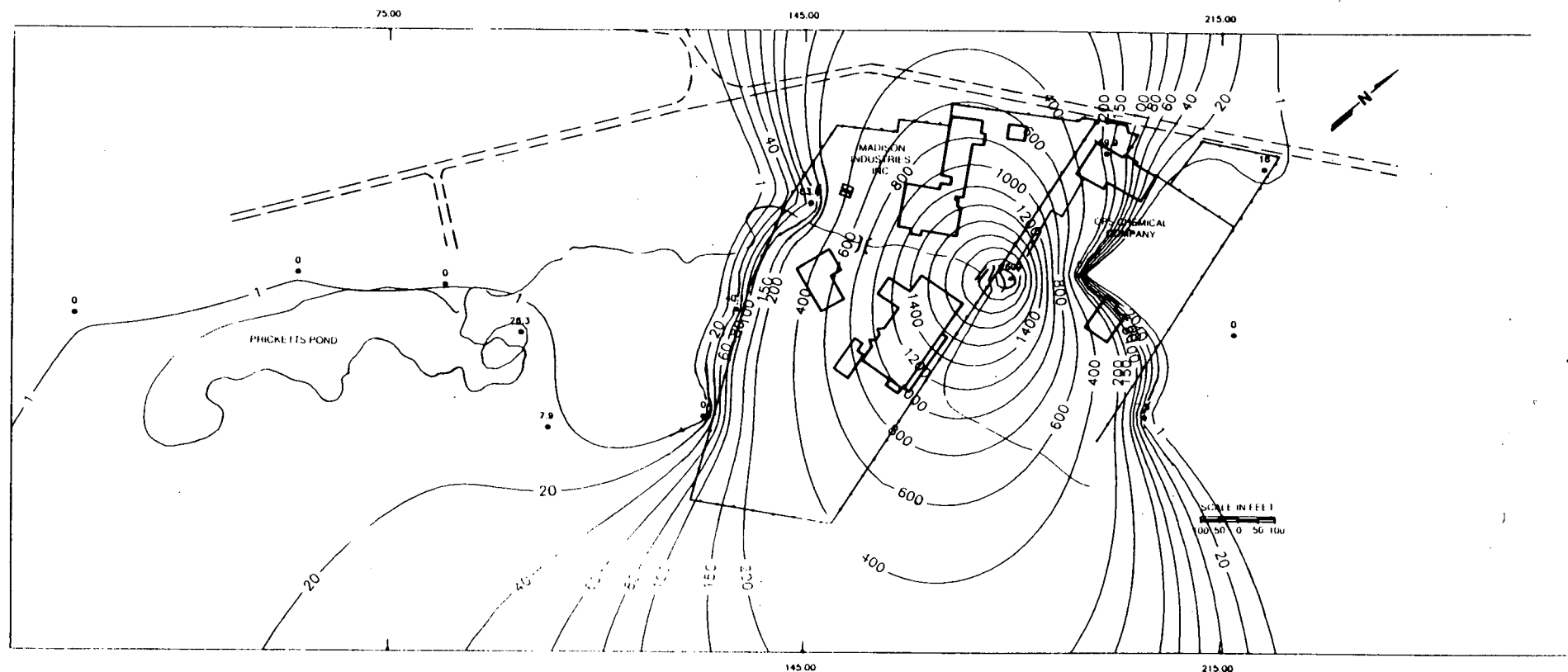


FIGURE 1-19d. 3-D PRESENTATION OF THE DIFFERENCE BETWEEN 1982 AND 1988
LEAD CONCENTRATIONS



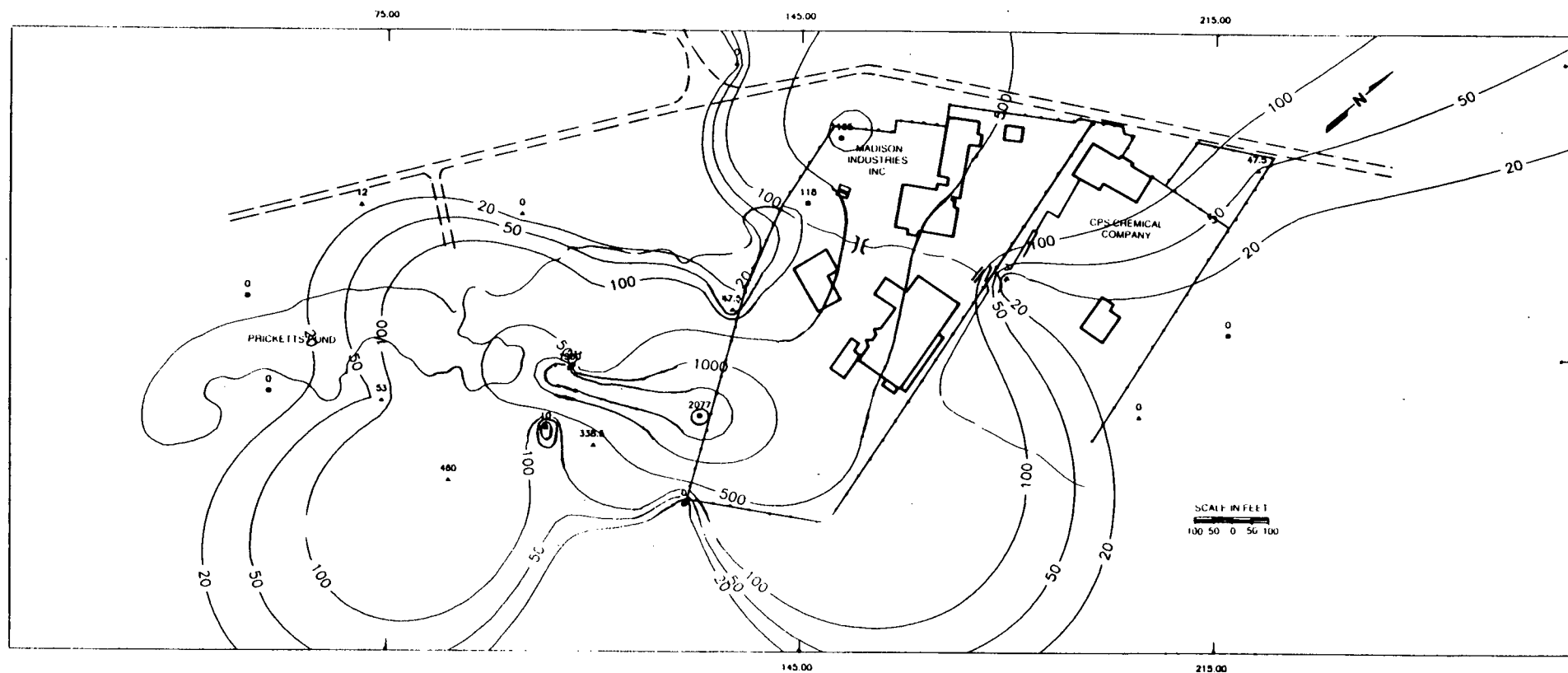
LEGEND:

- Well
- Well Cluster

— 100 — Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-20a. 1982 TVOC CONCENTRATIONS (ppb)



LEGEND:

- Well
- Well Cluster

— 100 — Concentration Contour, ppb

Note: All locations are approximate.

FIGURE 1-20b. 1988 TVOC CONCENTRATIONS (ppb)

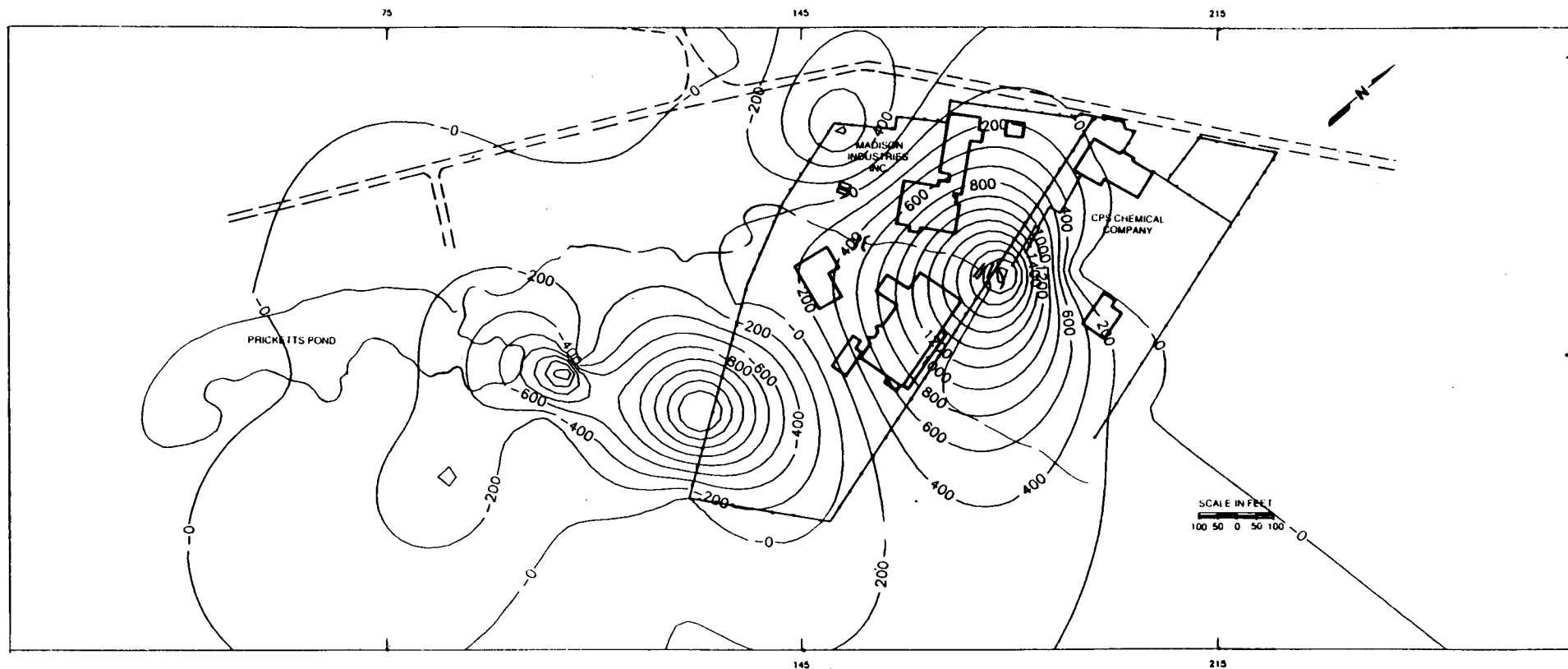
Pricketts Pond). The overall net concentration of TVOC in the groundwater has remained relatively constant between 1982 and 1988 (refer to Figures 1-20c and d). The change in the TVOC plumes between 1982 and 1988 represents a redistribution of TVOC concentrations with a gain in concentrations in downgradient areas and a loss of concentration at the CPS/Madison property boundary. TVOC does not appear to have migrated upgradient (i.e., east of the CPS property).

1.5.2.5 Summary

Several observations and conclusions can be made by comparing the contaminated groundwater plumes measured in 1982 and 1988 including the following:

This is migration spreading out?

- The concentration of cadmium, zinc, and lead show a net decrease in concentration between 1982 and 1988.
- The extent of the cadmium, zinc, and lead plumes have decreased and are centralized over the west end of the Madison property as a result of pumping well MI-T1.
- Areas of increasing concentrations (i.e., the concentration in 1988 was greater than the concentration in 1982) often correspond to areas of upward vertical hydraulic gradients.
- It is possible that more than one source of lead contamination, other than the Madison Industries, is present due to the high 1982 lead concentrations, measured upgradient and/or cross gradient of the Madison property.
- A pumping well located east of the CPS property could explain the apparent upgradient migration of the 1988 cadmium and zinc plume east of the CPS property.
- It is not clear how the upward vertical gradient, east of the CPS property, controls the migration of cadmium and zinc.
- The net concentration of TVOC appears to have remained constant over the study area; however, the concentration has been redistributed between 1982 and 1988. The TVOC



LEGEND:

— 40 — Contour of difference between 1982 and 1988 concentrations, ppb

FIGURE 1-20c. DIFFERENCE BETWEEN 1982 AND 1988 TVOC CONCENTRATIONS

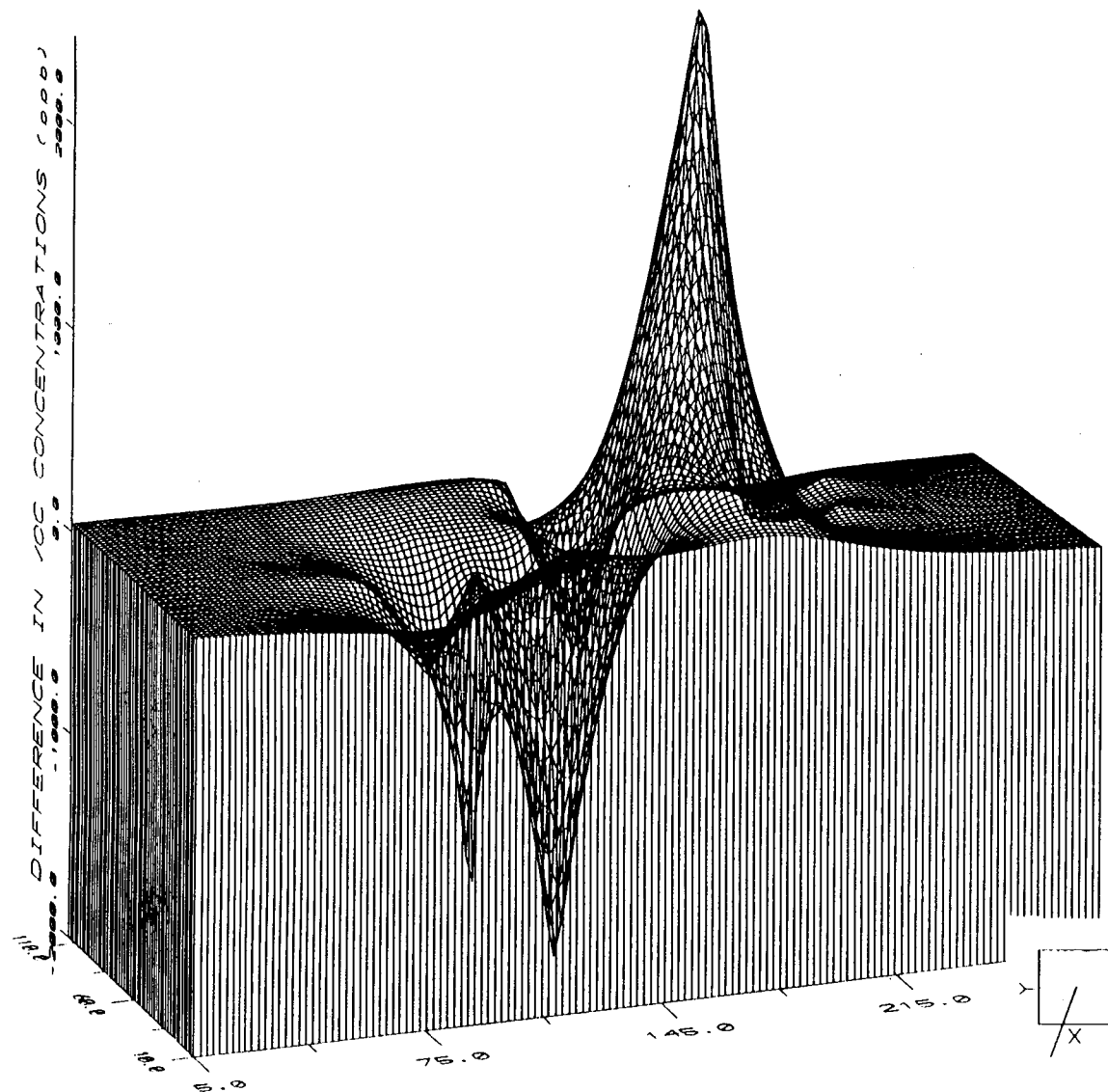


FIGURE 1-20d. 3-D PRESENTATION OF THE DIFFERENCE BETWEEN 1982 AND 1988 TVOC CONCENTRATIONS

plume has migrated and increased in concentration downgradient since 1982, whereas upgradient, in the vicinity of pumping well MI-T1, TVOC concentrations have decreased.

- The northern portion of Pricketts Pond and the area east of CPS property are both areas of upward vertical gradient and appear to have a significant control on contaminant migration.

1.5.3 The Future Fate and Transport of Contaminants

Assuming that the present flow conditions remain the same and pumping well MI-T1 is responsible for the reduction of the contaminant plumes, it is expected that metal concentrations will continue to decrease as a result of pumping well MI-T1. In addition, the metal contaminant plumes would be expected to remain centralized over the Madison property. Without the minimum information on pumping well MI-T1, such as the pumping rate and well depth, the influence of MI-T1 on the present and future concentrations of contaminants is speculative, however.

Although an actual net decrease in TVOC has not been observed over the entire site, at least part of the TVOC plume could also be affected by MI-T1, resulting in the reduction of TVOC concentrations. It is expected that pumping well MI-T1 would not be as effective in containing the TVOC plume as has been proposed for the metals since the source and highest concentrations of TVOC are cross-gradient and may not be affected by the cone-of-depression created by pumping well MI-T1.

1.6 BASELINE PUBLIC HEALTH RISK ASSESSMENT

The primary goal in conducting a baseline public health risk assessment of the CPS/Madison site is to evaluate the existing and potential risks to human health of exposure to chemicals present at or released from the facility. The objective is to

characterize the relative magnitude of the health risks and assess the need for site remediation. Typically, this evaluation would be conducted as part of the RI of a hazardous waste site. Because an RI has not been prepared for the CPS/Madison site, the baseline risk assessment is being conducted as part of the FS.

Groundwater is the primary environmental medium affected by contaminants released from the CPS/Madison site and is the focus of this baseline risk assessment.

The borough of Sayreville Water Department and the city of Perth Amboy have municipal water supply well fields in proximity to the CPS/Madison site (i.e., within 2,000 feet of the facility [TRC 1987]). As reported by TRC (1987), the Perth Amboy well field consists of four wells screened in the Old Bridge Aquifer and supplemented by a manifolded suction system of 40 vacuum wells 45 to 60 feet deep. The vacuum well system is not currently in operation (TRC 1987). The city of Perth Amboy well field serves approximately 55,000 people. The Sayreville well field comprises 17 wells (11 screened in the upper aquifer and 1 screened in the lower Farrington Aquifer) and serves approximately 33,000 people (TRC 1987). The major use of surface waters in the region surrounding the CPS/Madison site is as a source of recharge for water supply systems (TRC 1987).

As part of the RI of the Evor Phillips NPL site located upgradient from the CPS/Madison facility, an investigation was conducted of private wells within 1 mile of Evor Phillips. Data were obtained on the levels of chemicals in these wells. This area includes the region surrounding the CPS/Madison site. Results of the survey indicated that most private wells in the Old Bridge area are used for industrial purposes, such as cooling (TRC 1987). No private wells were identified within 1 mile of the Evor Phillips site. ATSDR, in a preliminary health

assessment of the CPS/Madison site, reported a population of 1,000 people within a 0.5 mile radius of the site. The Agency for Toxic Substances and Disease Registry also noted that the NJDEP is not aware of anyone currently exposed to contaminated groundwater in this region (ATSDR 1988).

The NJDEP Bureau of Potable Water collects water quality samples from the Sayreville supply wells. Data are available for the years 1981 to 1986. Analyses for volatile organics, heavy metals, and other inorganic constituents did not indicate "elevated levels" in any wells (TRC 1987). All organic compounds analyzed were below detection limits with the exception of trihalomethanes (maximum observed value of 3.0 ug/L for 1985). None of the compounds exceeded primary drinking water standards.

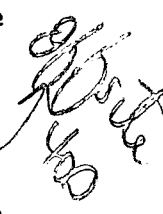
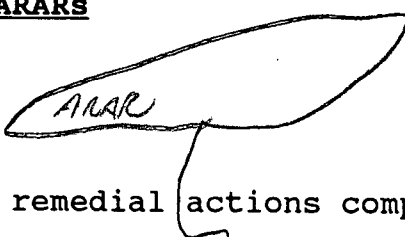
Given the available information, humans do not currently appear to be exposed to contaminants in groundwater in the upper aquifer downgradient of the CPS/Madison site. For the purposes of conducting a baseline risk assessment, however, a hypothetical exposure scenario has been developed that may serve as a basis for identifying and selecting remedial action alternatives. The focus of the risk assessment is the potential for adverse chronic effects following hypothetical long-term exposure to contaminants in groundwater. Both noncarcinogenic and carcinogenic effects are considered. Using conservative assumptions and the existing groundwater monitoring data, hypothetical estimates of chronic (i.e., long-term) exposure levels (dose) are derived. These are used in quantifying the potential risk of adverse health effects of exposure to groundwater. The results of the risk assessment may be considered an additional "tool" to be used in evaluating the magnitude and significance of observed levels of contamination at the site under investigation.

A number of studies of groundwater quality have been conducted over the last 10 years. Only two data sets have been found suitable for use in characterizing the extent of groundwater contamination, however (PAS 1982 and Wehran 1989). These data will be used in the identification and evaluation of chemical-specific applicable or relevant and appropriate requirements (ARARs) and in deriving dose estimates for use in the baseline risk assessment. (See Section 1.2 for a detailed discussion on the quality of monitoring data.)

1.6.1 Identification and Evaluation of ARARs

1.6.1.1 Background

Section 121 of CERCLA requires that remedial actions comply with Federal and State requirements that are legally ARARs are used under circumstances of the release or threatened release with respect to any hazardous substance or chemical that will remain onsite. As a matter of law, the requirements of Section 121 apply to remedial activities occurring onsite. However, the revised National Contingency Plan (NCP: [53 FR 51394]) notes that the U.S. Environmental Protection Agency (EPA) policy specifies attainment of ARARs "to the extent practicable considering the exigencies of the situation when carrying out removal actions." Therefore, ARARs must be attained for contaminant levels and performance standards at all points of potential exposure, or at the location specified by the ARAR itself (i.e., location- or action-specific requirements [USEPA 1988]).



ARARs are generally identified in increments of increasing certainty as the RI/FS proceeds. The process essentially begins after site characterization (RI) and may continue through the remedial design phase (FS [USEPA 1988]). During the phase of detailed analysis and selection of remedial alternatives (FS),

EPA indicates that potential ARARs should be evaluated according to the conditions at the site and the subset of remedial actions selected. This is done to determine if the potential ARARs are actually applicable or relevant and appropriate to the response action (53 FR 51394).

A Federal or State requirement (i.e., potential ARAR) may be "applicable" or "relevant and appropriate" but not both (USEPA 1988). EPA indicates that the identification and selection of ARARs can only be accomplished on a site-specific basis and involves the two-part analysis noted: (1) determination if a given requirement is applicable; and (2) if not applicable, then relevant and appropriate. Applicable requirements promulgated under Federal or State law will specifically address a hazardous substance or pollutant, action or location at a CERCLA (hazardous waste) site. Relevant and appropriate requirements, while not "applicable," address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular circumstance. EPA guidance on determining whether a requirement is applicable or relevant and appropriate is provided in CERCLA Compliance with Other Laws Manual (USEPA 1988).

According to EPA, when contaminated groundwater is the problem at a given site, remediation levels would generally be attained throughout the contaminated plume, or at and beyond the edge of the waste management area when waste is left in place (53 FR 51394). Preliminary remediation goals or cleanup levels are typically formulated during project scoping or concurrent with initial RI activities. Therefore, these preliminary cleanup levels are therefore initially based on readily available environmental or health-based ARARs and other criteria to be considered (TBC). The NCP indicates that as additional ARARs are identified during the RI, these preliminary remediation goals may

be modified as appropriate (as noted in the following paragraphs) to ensure overall protection to human health and the environment (53 FR 51394).

The stated goal of the EPA Superfund program with regard to groundwater contamination is "to return usable groundwaters to their beneficial uses within a timeframe that is reasonable given the particular circumstances of the site" (53 FR 51394). The first step in the process is to assess the characteristics of the affected groundwater. A determination needs to be made as to whether the contaminated groundwater should be classified as Class I, II, or III waters.

- Class I groundwaters are irreplaceable sources of drinking water, or ecologically vital, and are highly vulnerable to contamination.
- Class II groundwaters are all "non-Class I" waters that are currently used (Class II-A) or are potentially available (Class II-B) for drinking water or other beneficial uses.
- Class III groundwaters are not useable/suitable as a source of drinking water.

The revised NCP indicates that for groundwater that is or may be used for drinking water (Class I or II), the maximum contaminant levels (MCLs) set under the Safe Drinking Water Act or more stringent promulgated State standards are generally the applicable or relevant and appropriate standard (53 FR 51394). Further, the NCP states that in cases involving multiple contaminants or pathways that present (excess lifetime cancer) risks in excess of 10^{-4} , maximum contaminant level goals (MCLGs) may be considered when determining acceptable exposure levels. Federal ambient water quality criteria (FWQC) adjusted for drinking water only may also be found to be relevant and appropriate. [It is EPA's position that] if a promulgated MCL is available for a given chemical, FWQC would not be relevant and

appropriate. In the absence of an MCL, however, the FWQC may be an ARAR in water that is a potential drinking water source (53 FR 51394).

In the NCP, EPA notes that chemical-specific ARARs are generally set for a single chemical or closely related group of chemicals, and that these requirements typically do not consider exposure to multiple chemicals or via multiple pathways. Therefore, proposed remediation goals may not always be protective of human health or the environment if established at the level of single chemical-specific requirements (ARARs). EPA specifies that remediation goals may be set at levels more stringent than chemical-specific ARARs in order to obtain a remedy that is protective (USEPA 1988, 53 FR 51394). EPA considers remedies to be protective if the resulting excess lifetime cancer risk falls within the range of 10^{-7} to 10^{-4} , and if dose estimates do not exceed acceptable levels of exposure for noncarcinogenic effects.

1.6.1.2 Identification of Potential Chemical-Specific ARARs at the CPS/Madison Site

As noted by EPA and discussed previously, the identification and selection of ARARs is an ongoing and iterative process, beginning at the site investigation phase and reaching completion during the FS. At this point in the assessment of the CPS/Madison site, it is appropriate to identify potential ARARs that may be used in the development of remediation goals (cleanup levels).

A chemical-specific criterion or standard becomes an ARAR if it is found to be applicable or relevant and appropriate to the particular circumstances at a waste site under investigation. The distinction between applicable and relevant and appropriate

requirements has been defined previously. These two classes of requirements also differ in the amount of discretion allowed in their identification. The revised NCP notes that applicable requirements are identified by a largely objective comparison to the circumstances at the site (53 FR 51394). A chemical-specific requirement is considered applicable if there is a one-to-one correspondence between the requirement and the circumstances at the site. EPA indicates that there is little discretion involved in this determination. Relevant and appropriate requirements, however, are determined using best professional judgement as to whether the requirement addresses problems or situations that are generally pertinent to conditions at the site (i.e., relevant) and "well-suited" (i.e., appropriate as a remediation goal).

At the CPS/Madison site, none of the identified Federal criteria and standards (i.e., MCLs, MCLGs, and FWQC) may be considered "applicable" requirements for groundwater. None of these requirements specifically address the circumstances of observed groundwater contamination at the site. The MCLs and MCLGs would be applicable if site-related chemicals were observed in a public water supply system, and contamination was present at the tap. (The same reasoning is appropriately used for the New Jersey State drinking water standards). FWQC were developed for surface water systems and although these requirements may be relevant and appropriate for groundwater in the absence of MCLs, they are clearly not "applicable" as remediation guidelines for groundwater.

MCLs for a toxic chemical are enforceable EPA standards and are allowable limits for lifetime exposure to the contaminant in public drinking water supplies. The MCL is established taking into consideration potential health effects and the feasibility of attaining such a concentration given the best available technology, treatment techniques, and costs. }

As part of the process for developing a final drinking water standard MCL, MCLGs are developed. MCLGs are nonenforceable health-based guidelines established at concentrations that are associated with no known or anticipated adverse health effects for chemicals in public drinking water supplies. MCLs are set at concentrations as close to MCLGs as is feasible.

FWQC are guidelines for chemicals in surface waters developed by the EPA Office of Water Regulations and Standards for the protection of aquatic life and human health. Although these are not enforceable standards, they represent scientific data and guidance to be used by the States in developing water quality standards.

State environmental standards are those promulgated by the State for the protection of environmental quality and may be applicable or relevant and appropriate for evaluating remedial actions at waste sites in that State. The availability of, and numerical values for these standards vary widely from State to State. If State standards are available, and if these are different from the ARARs proposed by EPA, then EPA guidance specifies that the more stringent of the two standards be used in waste site evaluation (53 FR 51394).

According to EPA, a requirement may be determined to be relevant and appropriate if the established health or environmental limit is based on an exposure scenario that is similar to the potential exposure at a CERCLA site (53 FR 51394). EPA considers this to be the focal point for determining if a requirement is relevant and appropriate. The objective of the Safe Drinking Water Act (SDWA) is to ensure that potable water supplies are safe for human consumption. At the CPS/Madison site, the primary regulatory concern is that groundwater contamination may preclude use of a potential source of drinking

water. Based on this comparison, the situation at the waste site is sufficiently similar to the problems addressed by the SDWA that MCLs would be considered relevant requirements.

EPA has determined, as a matter of policy, that MCLs will be relevant and appropriate for groundwater or surface water that currently is or may in the future be used directly for drinking (USEPA 1988). The Agency points out that although groundwater beneath a waste site under investigation may not be a current source of public drinking water and the wells do not belong to a public water system (and therefore do not meet the jurisdictional prerequisites for the SDWA), the water may still be a potential future source of drinking water (provided it is not a Class III aquifer). EPA concludes that because the contaminated groundwater may be used directly as a potable supply in the future, MCLs should be identified as a "probable relevant and appropriate standard" (USEPA 1988).

For the CPS/Madison site, MCLGs and FWQC were also identified as potential ARARs. As noted above, EPA considers MCLGs relevant and appropriate for evaluating groundwater (i.e., as a potential drinking water sources) when multiple contaminants or pathways may present excess lifetime cancer risks in exceeding 10^{-4} . FWQC were included at this stage as an additional point of comparison for chemical for which MCLs are not available. EPA indicates that FWQC adjusted for drinking water only may be relevant and appropriate under such circumstances.

1.6.1.3 Comparison of Groundwater Contaminant Levels with ARARs

Concentrations of chemicals in groundwater downgradient of the CPS/Madison site are evaluated by comparing the mean and maximum observed levels with potentially relevant and appropriate

Federal and State ARARs. Table 1-10 is a listing of water quality ARARs and other values to be considered in this assessment. The primary ARARs of importance for chemical contaminants in groundwater at Operable Unit 1 are: (1) the MCLs developed by the EPA Office of Drinking Water, and (2) the New Jersey State drinking water standards. The EPA FWQC (adjusted for drinking water) are used more appropriately in evaluating the significance of contamination in surface water systems. As specified by EPA, FWQC (adjusted for drinking water only) may become relevant and appropriate for a given chemical in groundwater when an MCL is not available for this compound. Note that Federal or State ARARs are currently not available for chemical contaminants in soil. New Jersey has developed "action levels" for chemicals in soils, but these guidelines are not formally promulgated and therefore, are additional values "to be considered" only.

Table 1-11 provides a summary of mean and maximum levels of chemicals in groundwater downgradient of the CPS/Madison site and an indication of the compounds that exceed potential ARARs. As shown, mean concentrations of the following chemicals exceed Federal or State primary drinking water standards--cadmium, benzene, carbon tetrachloride, 1,2-dichloroethane, 1,2-dichloroethylene, and trichloroethylene. When Federal or State drinking water standards are not available, an indication is made of those compounds exceeding FWQC adjusted for drinking water only --chloroform, hexachlorobenzene, hexachlorobutadiene, methylene chloride, and 1,1,2,2-tetrachloroethane.

The same results noted above apply to the maximum observed values in groundwater. In addition, the maximum concentrations of the following chemicals were found to exceed Federal or State drinking water standards--1,2-dichloroethane, 1,1,1-trichloroethane, and vinyl chloride. Note that proposed MCLs and

TABLE 1-10. WATER QUALITY ARARs AND DRINKING WATER HEALTH ADVISORIES FOR CHEMICALS AT THE CPS/MADISON SITE

CHEMICAL	MCLs(a) (UG/L)	MCLGs(b) (UG/L)	FWQC-HH (c) HUMAN HEALTH: ADJUSTED FOR DRINKING WATER ONLY (UG/L)	FWQC-A (c) FRESHWATER ACUTE VALUE: AQUATIC LIFE (UG/L)	FWQC-C (c) FRESHWATER CHRONIC VALUE: AQUATIC LIFE (UG/L)	NEW JERSEY STATE WATER QUALITY STANDARDS (n) (UG/L)	FEDERAL DRINKING WATER HEALTH ADVISORIES (j)			
							ONE-DAY 10 KG (k) (UG/L)	TEN-DAY 10 KG (k) (UG/L)	LONGER-TERM 70-KG (m) (UG/L)	LIFETIME HEALTH ADVISORY (UG/L)
INORGANICS										
Cadmium	10	5 d	10	3.9	1.1	3.7, 0.1, 10.	43	43	5	5
Copper	1300 d	1300 d	1000 g	18	12					
Lead	50 p	20 d	50	82	3.2	50., .05, 50.				
Zinc	5000 e		5000 g	120	110				20 ug/day	
ORGANICS										
Acenaphthalene										
Acenaphthene										
Benzene	5	0	0.67 f	5300		1., N/A, N/A	235	235		
Bis(2-Ethylhexyl)phthalate			21000	940	3					
Bromoform	100 h									
Carbon Tetrachloride	5	0	0.42 f	35200		2., N/A, N/A	4000	160	71	
Chlorobenzene		60 d	488	250	50	4., N/A, N/A	4300	4300	4300	300
Chloroform	100 h		0.19 f	28900	1240					
Chloromethane										
Chrysene										
1,2-Dichlorobenzene	600 d	620 d	470	1120	763	600., N/A, N/A	8930	8930	8930	620
1,3-Dichlorobenzene						600., N/A, N/A				
1,4-Dichlorobenzene	75	75	470	1120	763	6., N/A, N/A	10700	10700	10700	75
1,1-Dichloroethane										
1,2-Dichloroethane	5	0	0.94 f	118000	20000	2., N/A, N/A	740	740	740	
1,1-Dichloroethylene	7	7	0.033 f	11600		2., N/A, N/A	2000	1000	1000	7
Trans-1,2-Dichloroethylene	100 d	100 d		11600		2., N/A, N/A	20000	1430	1430	70
1,2-Dichloropropane	5 d	0 d		23000	5700			90		
Dimethyl phthalate										
Ethylbenzene	700 d	700 d	2400	32000			32000	3200	3400	680

a. Maximum Contaminant Levels established under the Safe Drinking Water Act.

b. Maximum Contaminant Level Goal established under the Safe Drinking Water Act.

c. Federal Ambient Water Quality Criteria (FWQC) for human health and aquatic life established under the Clean Water Act.

d. Proposed MCL or MCLG: Federal Register May 22, 1989; August 18, 1988; or November 13, 1985.

e. Secondary Maximum Contaminant Level (SMCL) established under the Safe Drinking Water Act - not an ARAR.

f. FWQC-HH for human health corresponding to the 10-6 risk level.

g. Criterion established based on taste and odor effects (organoleptic), not human health effects.

h. Maximum Contaminant Level for total trihalomethanes: the sum concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.

i. FWQC-HH for halomethanes as a class of compounds corresponding to the 10-6 risk level. Methylene chloride (dichloromethane) is a member of this class this group.

j. Federal Drinking Water Health Advisories are not ARARs but values to be considered (TBC) in evaluating the significance of observed levels of contamination in drinking water supplies. Information obtained from USEPA (1986, 1987a,b,c).

k. Drinking Water Health Advisory for a 10-kg child.

m. Drinking Water Health Advisory for a 70-kg adult.

n. New Jersey Department of Environmental Protection water quality ARARs. First number is NJ Safe Drinking Water Act and A-280 Amendments MCLs. Second number is NJ Water Pollution Control Act primary standards for ground water class GW-1 (Central Pine Barrens) as per NJAC 79-6.6(a). The third number is the NJ Water Pollution Control Act criteria for surface water classes SE (saline estuary), SC (saline coastal), and FW2 (general freshwater). For classes FW1 (within national or state parks) or PL (within the Pinelands) surface water must be maintained in its natural state of quality. Note that "blank" entries in the table = N/A.

p. A proposed revision to MCL for lead of 5. ug/L was published in 53 FR 31516 (August 18, 1988).

TABLE 1-10. WATER QUALITY ARARs AND DRINKING WATER HEALTH ADVISORIES FOR CHEMICALS AT THE CPS/MADISON SITE (CONTINUED)

CHEMICAL	MCLs(a) (UG/L)	MCLGs(b) (UG/L)	FWQC-HH (c) HUMAN HEALTH: ADJUSTED FOR DRINKING WATER	FWQC-A (c) FRESHWATER ACUTE VALUE: AQUATIC LIFE	FWQC-C (c) FRESHWATER CHRONIC VALUE: AQUATIC LIFE	NEW JERSEY STATE WATER QUALITY STANDARDS (n) (UG/L)	FEDERAL DRINKING WATER HEALTH ADVISORIES (j)			
			ONLY (UG/L)	(UG/L)	(UG/L)		(UG/L)	ONE-DAY 10 KG (k) (UG/L)	TEN-DAY 10 KG (k) (UG/L)	LONGER-TERM 70-KG (m) (UG/L)
Hexachlorobenzene			0.021 f				50	50	175	
Hexachlorobutadiene			0.45 f	90	9.3					
Hexachlorocyclopentadiene				7	5.2					
Methylene Chloride			0.19 i	11000		2., N/A, N/A	13300	1500		
N-Nitrosodiphenylamine										
1,1,2,2-Tetrachloroethane			0.17 f	9320						
Tetrachloroethylene	5 d	0 d	0.88 f	9320		1., N/A, N/A	2000	2000	1400	
Toluene	2000 d	2000 d	15000	17500			21500	3460	3460	2420
1,1,1-Trichloroethane	200	200	19000			26., N/A, N/A	140000	35000	35000	200
1,1,2-Trichloroethane			0.6 f							
Trichloroethylene	5	0	2.8 f	45000	21900	1., N/A, N/A	N/A	N/A	N/A	
Vinyl chloride	2	0	2 f			2., N/A, N/A	2600	2600	13	
Xylenes	10000 d	10000 d				44., N/A, N/A	12000	7800	7800	400

- a. Maximum Contaminant Levels established under the Safe Drinking Water Act.
b. Maximum Contaminant Level Goal established under the Safe Drinking Water Act.
c. Federal Ambient Water Quality Criteria (FWQC) for human health and aquatic life established under the Clean Water Act.
d. Proposed MCL or MCLG: Federal Register May 22, 1989; August 18, 1988; or November 13, 1985.
e. Secondary Maximum Contaminant Level (SMCL) established under the Safe Drinking Water Act - not an ARAR.
f. FWQC-HH for human health corresponding to the 10⁻⁶ risk level.
g. Criterion established based on taste and odor effects (organoleptic), not human health effects.
h. Maximum Contaminant Level for total trihalomethanes: the sum concentration of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.
i. FWQC-HH for halomethanes as a class of compounds corresponding to the 10⁻⁶ risk level. Methylene chloride (dichloromethane) is a member of this class this group.
j. Federal Drinking Water Health Advisories are not ARARs but values to be considered (TBC) in evaluating the significance of observed levels of contamination in drinking water supplies. Information obtained from USEPA (1986, 1987a,b,c).
k. Drinking Water Health Advisory for a 10-kg child.
l. Drinking Water Health Advisory for a 70-kg adult.
m. New Jersey Department of Environmental Protection water quality ARARs. First number is NJ Safe Drinking Water Act and A-280 Amendments MCLs. Second number is NJ Water Pollution Control Act primary standards for ground water class GW-1 (Central Pine Barrens) as per NJAC 79-6.6(a). The third number is the NJ Water Pollution Control Act criteria for surface water classes SE (saline estuary), SC (saline coastal), and FW2 (general freshwater). For classes FW1 (within national or state parks) or PL (within the Pinelands) surface water must be maintained in its natural state of quality. Note that "blank" entries in the table = N/A.
n. A proposed revision to MCL for lead of 5. ug/L was published in 53 FR 31516 (August 18, 1988).

TABLE 1-11. COMPARISON OF GROUNDWATER LEVELS WITH ARARS: CPS/MADISON FACILITY

CHEMICAL	Mean (a) Concentration in Groundwater (ug/L)	Maximum Concentration in Groundwater (ug/L)	Comparison: Mean Concentration vs. ARAR	Comparison: Maximum Concentration vs. ARAR
INORGANICS				
Cadmium	76.15	2010	> MCL, 50; > FWQC 10 ug/L)	> MCL, 50; > FWQC 10 ug/L)
Copper	871.96	24000		> pMCL, 1300 ug/L)
Lead	56.80	442	> MCL, 50; > NJ MCL 50 ug/L	> MCL, 50; > NJ MCL 50 ug/L
Zinc	25398.00	779000	Exceeds secondary MCL	Exceeds secondary MCL
ORGANICS				
Acenaphthene	1.10	23		
Acenaphthylene	2.19	46		
Benzene	15.10	310	> MCL, 5; > NJ MCL 1. ug/L	> MCL, 5; > NJ MCL 1. ug/L
Bis(2-ethylhexyl)phthalate	21.76	175		
Bromoform	9.45	205		
Carbon Tetrachloride	133.15	4480	> MCL, 5; > NJ MCL 2. ug/L	> MCL, 5; > NJ MCL 2. ug/L
Chlorobenzene	46.13	1100	> NJ MCL 4. ug/L	> pMCLG, 60; > NJ MCL 4. ug/L
Chloroform	25.48	1070	> FWQC, (0.19 ug/L)	> FWQC, (0.19 ug/L)
Chloromethane	0.31	13		
Chrysene	1.14	24		
1,3-Dichlorobenzene	1.00	21		
1,4-Dichlorobenzene	1.00	21		> NJ MCL 6. ug/L
1,2-Dichloroethane	31.29	670	> MCL, 5; > NJ MCL 2. ug/L	> MCL, 5; > NJ MCL 2. ug/L
1,1-Dichloroethane	5.55	206		
1,2-Dichloroethylene	18.27	400	> NJ MCL 2. ug/L	> pMCL 100; > NJ MCL 2. ug/L
1,2-Dichloropropane	6.56	122	> pMCL, 5 ug/L	> pMCL, 5 ug/L
Dimethyl Phthalate	5.67	93		
Ethylbenzene	7.98	87		
Hexachlorobenzene	2.52	53	> FWQC, (0.021 ug/L)	> FWQC, (0.021 ug/L)
Hexachlorobutadiene	3.48	73	> FWQC, (0.45 ug/L)	> FWQC, (0.45 ug/L)
Hexachlorocyclopentadiene	8.76	184		
Methylene Chloride	261.45	10595	> FWQC, (0.19 ug/L) (b)	> FWQC, (0.19 ug/L) (b)
N-Nitrosodiphenylamine	23.57	471		
1,1,2,2-Tetrachlorethane	1.83	59	> FWQC, (0.17 ug/L)	> FWQC, (0.17 ug/L)
Tetrachloroethylene	0.70	24		> pMCL 5 ug/L; > NJ MCL 1. ug/L
Toluene	54.39	980		
1,1,1-Trichloroethane	54.20	2200		> MCL 200; > NJ MCL 26. ug/L
Trichloroethylene	16.99	524	> MCL 5 ug/L; > NJ MCL 1. ug/L	> MCL 5 ug/L; > NJ MCL 1. ug/L
Vinyl Chloride	0.37	11		> MCL 2 ug/L; > NJ MCL 2. ug/L
Xylenes	16.37	185		

MCL = Maximum Contaminant Level. USEPA Primary Drinking Water Standards. pMCL = proposed MCL.

MCLG = Maximum Contaminant Level Goal. USEPA health-based guideline used in the development of MCLs. pMCLG = proposed MCLG.

FWQC = Federal Ambient Water Quality Criteria adjusted for drinking water only.

() = FWQC values corresponding to the 10⁻⁶ risk level.

a. Arithmetic mean of yearly means for sampling sets 1982 and 1988.

b. FWQC for halomethanes as a class of compounds corresponding to the 10⁻⁶ risk level.

Methylene chloride (dichloromethane) is a member of this group.

MCLGs are not yet considered ARARs. A comparison with these values has been included, however.

1.6.2 Assumptions Used in the Baseline Risk Assessment

It is essential that the results of risk assessment be interpreted with regard to the assumptions adopted in the analysis. Given that the toxicity measures used in the assessment are established by EPA, the greatest source of uncertainty becomes the development of exposure scenarios and the derivation of long-term dose estimates for the human receptors at greatest risk. Assumptions that are the foundation of this preliminary risk assessment at the CPS/Madison site are outlined in detail below.

1.6.2.1 General Assumptions

- The baseline risk assessment examines the hypothetical risk to human health of exposure to contaminated groundwater from the Old Bridge Aquifer downgradient of the CPS/Madison site. The objective was to develop a reasonable (although hypothetical) upper-bound estimate of long-term exposure and a measure of the likelihood of adverse effects.
- Hypothetical risks to human health are characterized for ingestion exposure to chemicals in solution and inhalation exposure to volatile compounds released to the air during showering and other indoor uses of the groundwater. The assessment evaluates combined exposure across chemicals and exposure pathways.
- Monitoring data for 1982 and 1988 data were pooled, and the mean values derived were used as the "most representative" measure for developing exposure/dose estimates. "Not detected" results were treated as 0.0 and included in the calculation of the arithmetic mean.
- The potential for both carcinogenic and noncarcinogenic effects are evaluated. The toxicity measures used in the assessment are those most currently available from EPA and were obtained from the IRIS on-line data base, the EPA Superfund Public Health Evaluation Manual (SPHEM

[USEPA 1986]), or the March 1989 update to the SPHEM. There is often a considerable amount of uncertainty associated with these measures. EPA reserves the right to review and revise or update these essential toxicity values as new scientific information becomes available. The results of risk assessment may change dramatically as new toxicity measures become available. In the absence of essential EPA toxicity data for several chemicals present in groundwater at CPS/Madison, surrogate measures have been adopted based on structural or toxicological similarities (see Appendix A.11). If there was not a reasonable basis for adopting a surrogate measure for a given chemical, this compound was not included in the evaluation.

1.6.2.2 Exposure to Groundwater

- Because groundwater downgradient of the CPS/Madison site is not currently used domestically (i.e., as a source of drinking water and for bathing), it is not possible to estimate or project the intensity, duration, and frequency of exposure from a knowledge of actual community use of this water source. Therefore, it is necessary to construct a hypothetical exposure scenario to serve as the basis of the risk assessment.
- For the purpose of developing an upper-bound estimate of risks to human health, it has been assumed that groundwater at each site under investigation is used as a source of drinking water. Exposure/dose estimates are developed assuming hypothetical ingestion of 2 liters of water per day, by a 70-kilogram adult, over a 70-year lifetime.
- Several models are available in the scientific literature that may be used to estimate exposure/dose from inhalation of vapors released during showering and other indoor domestic water uses (e.g., see McKone 1987 ES&T 21: 1194-1201). These models have not been critically reviewed and verified by EPA. EPA has recommended therefore, that for the average case, it should be assumed that the inhalation risks associated with domestic water use are equal to that of ingesting 2 liters of water per day. EPA guidance has been provided by the Office of Drinking Water (USEPA 1984) and the Office of Solid Waste and Emergency Response (OSWER Directive 9360.1-01, October 1987). EPA Region X has also adopted and recommends this approach (see Statement of Work for the RI/FS Human Health Risk Assessment and

the associated Appendix, prepared by EPA Seattle as guidance in the risk assessment process).

- This baseline assessment incorporates consideration of the inhalation exposure pathway by using 4 liters per day as the combined intake factor for ingestion and inhalation pathways. As structured, the inhalation exposure estimate assumes that the maximally exposure individual showers (i.e., or is exposed to volatiles released during the showering event in indoor air) every day, each week, over a 70-year lifetime. For the purposes of this evaluation, volatile organic compounds were conservatively defined as chemicals with a vapor pressure greater than 1 mm Hg at 20 to 25° C.
- In the absence of specific information on the frequency of dermal contact with contaminated groundwater, general assumptions are made regarding exposure via this route. Based upon EPA guidance, it is assumed that dermal absorption would contribute approximately 1.5 percent of the oral dose experienced by the "average adult" (USEPA 1984). In the 1984 study by the Office of Drinking Water, EPA indicates that dermal absorption is not considered "a significant source of exposure and risk [relative to ingestion and inhalation]" for volatile organic compounds in drinking water. Therefore, dermal absorption has not been incorporated into the baseline risk assessment.
- All chemicals present in groundwater are assumed to be 100 percent bioavailable and are completely absorbed into the bloodstream following ingestion or inhalation.
- All chemicals are considered to be conservative in the environment (i.e., that physical/chemical or biological transformation does not remove the subject compounds from the environment). Thus, uniform long-term exposure is thus projected based upon the mean of the two sets (i.e., 1982 and 1988) of monitoring data available.

1.6.3 Results and Conclusions

Table 1-12 presents the results of the risk characterization for groundwater in the vicinity of the CPS/Madison site. As shown, the table presents: (1) the monitoring data used as the basis of the assessment (mean and maximum environmental concentrations for the combined data), (2) an estimate of chronic

TABLE 1-12. RISK CHARACTERIZATION FOR CPS/MADISON FS: GROUNDWATER EXPOSURE

Chemical	Mean (a) Concentration in Groundwater (ug/L)	Maximum (b) Concentration in Groundwater (ug/L)	Number of Samples (c)	Number of Samples Greater than DL (d)	Chronic Dose Based on Combined Mean Estimates (f) (mg/kg/day)	Hazard Index for Chronic Exposure (g) (Dose/RfD)	Excess Lifetime Cancer Risk (h) (Dose x q1*)
INORGANICS							
Cadmium	76.15	2010	51	16	2.18E-03	4.35E+00	
Copper	871.96	24000	51	38	2.49E-02		
Lead	56.80	442	51	37	1.62E-03	1.16E+00	
Zinc	25398.00	779000	51	51	7.26E-01	3.63E+00	
ORGANICS							
Acenaphthene	1.10	23	21	1	3.13E-05		
Acenaphthylene	2.19	46	21	1	6.26E-05		
Benzene	15.10	310	51	17	8.63E-04 v(e)		2.50E-05
Bis(2-ethylhexyl)phthalate	21.76	175	21	9	6.22E-04	3.11E-02	8.70E-06
Bromoform	9.45	205	51	5	2.70E-04		
Carbon Tetrachloride	133.15	4480	51	10	7.61E-03 v	1.09E+01	9.89E-04
Chlorobenzene	46.13	1100	51	12	2.64E-03 v	1.26E-01	
Chloroform	25.48	1070	51	1	1.46E-03 v	1.46E-01	8.88E-06
Chloromethane	0.31	13	51	1	1.77E-05 v		
Chrysene	1.14	24	21	1	3.26E-05		
1,3-Dichlorobenzene	1.00	21	21	1	5.71E-05 v	1.43E-04	
1,4-Dichlorobenzene	1.00	21	21	1	5.71E-05 v	1.43E-04	1.37E-06
1,2-Dichloroethane	31.29	670	51	19	1.79E-03 v	1.49E-02	1.63E-04
1,1-Dichloroethane	5.55	206	51	3	3.17E-04 v	2.64E-03	2.89E-05
1,2-Dichloroethylene	18.27	400	30	8	1.04E-03 v		
1,2-Dichloropropane	6.56	122	51	8	3.75E-04 v		2.55E-05
Dimethylphthalate	5.67	93	21	2	1.62E-04		
Ethylbenzene	7.98	87	51	13	4.56E-04 v	4.56E-03	
Hexachlorobenzene	2.52	53	21	1	7.21E-05	9.01E-02	1.23E-04
Hexachlorobutadiene	3.48	73	21	1	1.99E-04 v	9.93E-02	1.55E-05
Hexachlorocyclopentadiene	8.76	184	21	1	2.50E-04	3.58E-02	
Methylene Chloride	261.45	10595	51	7	1.49E-02 v	2.49E-01	1.12E-04
N-Nitrosodiphenylamine	23.57	471	21	2	6.73E-04		3.30E-06
1,1,2,2-Tetrachlorethane	1.83	59	51	3	1.05E-04 v		
Tetrachloroethylene	0.70	24	51	2	4.00E-05 v	4.00E-03	2.04E-06
Toluene	54.39	980	51	15	3.11E-03 v	1.04E-02	
1,1,1-Trichloroethane	54.20	2200	51	5	3.10E-03 v	3.44E-02	
Trichloroethylene	16.99	524	51	12	9.71E-04 v	9.71E-02	1.07E-05
Vinyl Chloride	0.37	11	30	1	2.10E-05 v		4.82E-05
Xylenes	16.37	185	21	7	9.35E-04 v	4.68E-04	
Hazard Index: Combined Exposure						2.10E+01	
Excess Lifetime Carcinogenic Risk: Combined Exposure							1.56E-03

- a. Arithmetic mean of combined data set sampled 3/82 (PAS 1982) and 11/14-16/88 (Wehran 1989). "Not detected" results were treated and included in the calculation of the mean.
- b. The maximum concentration for all selected wells from both data sets, 1982 and 1989.
- c. The sum of the number of samples for both data sets.
- d. The number of samples indicating groundwater concentrations above the detection limit.
- e. Indicates the chemicals that are considered volatile compounds (v) for the purpose of the risk assessment.

(long-term) dose, (3) the value of the hazard index (HI), a measure of the potential for adverse noncarcinogenic effects, and (4) an estimate of the excess (i.e., additional beyond everyday exposure) lifetime carcinogenic risk to a hypothetically maximally exposed individual. Risk estimates are provided separately for each subject chemical and for the combined exposure across chemicals for the ingestion and inhalation exposure routes.

As shown in Table 1-12, the potential exists for adverse noncarcinogenic effects following hypothetical exposure to groundwater downgradient from the CPS/Madison site. The HI for the combined exposure across compounds is calculated to be considerable greater than 1.0 (approximately 21.) (See Appendix H for further discussion of the HI and its meaning.) The primary noncarcinogenic risks are associated with the following compounds: cadmium (HI = 4.0), zinc (HI = 3.6), and carbon tetrachloride (HI = 10.9).

In general, if the HI score exceeds 1.0 for the combined exposure across subject chemicals, EPA recommends "desegregating" the chemicals, and reevaluating the potential for adverse noncarcinogenic effects focusing on groups of compounds that affect similar target organ systems (e.g., central nervous system, kidney, and blood system). A new HI score would then be calculated for subsets of the chemicals having common target organ effects. Given that the HI for several chemicals exceeds 1.0 by a substantial margin, this subsequent analysis is not essential to the baseline assessment.

The excess lifetime risk of cancer was estimated for hypothetical exposure to mean levels of potential carcinogens in groundwater downgradient of the CPS/Madison site. As noted previously, dose estimates were derived assuming ingestion of 4

liters of water per day by a 70-kg adult, over a 70-year lifetime. The 4-liter assumption accounts for exposure via both the ingestion and inhalation pathways. Note again, that the added exposure factor of 2 liters per day was included only for volatile organic compounds.

The excess lifetime risk of cancer exceeds the 10^{-4} risk level for combined exposure across chemicals, and across the ingestion and inhalation pathways. The excess cancer risk to the maximally exposed individual was determined to be approximately 1.6×10^{-3} (i.e., an additional probability of cancer of 1.6 in 1,000). As shown in Table 1-12, the primary cancer risk is associated with the hypothetical exposure to the following chemicals:

- Carbon tetrachloride (excess cancer risk = 9.9×10^{-4})
- 1,2-Dichloroethane (excess cancer risk = 1.6×10^{-4})
- Hexachlorobenzene (excess cancer risk = 1.2×10^{-4})
- Methylene chloride (excess cancer risk = 1.0×10^{-4})
- Vinyl chloride (excess cancer risk = 4.8×10^{-5})
- Benzene (excess cancer risk = 3.6×10^{-5}).

Given EPA guidelines for waste site evaluation, discussed previously, this combined excess lifetime cancer risk would be considered unacceptably high.

Note that from the available data, it is not possible to conclude that the volatile organic contaminants in groundwater originate solely from the CPS/Madison facility. Release of contaminants from the Evor Phillips site upgradient of CPS/Madison may be contributing to the observed levels of chemicals downgradient of the CPS/Madison site. The results of the baseline risk assessment must be qualified by this observation.

1.7 SUMMARY

~~The CPS Company/Madison site is the tenth highest ranking Superfund site on the NPL.~~ The site is located within the Pricketts Brook Watershed, in Old Bridge Township, Middlesex County, New Jersey. The major contaminants of concern investigated in groundwater, soil, surface water, and sediment are zinc, lead, cadmium, methylene chloride, and 1,1,2,2-tetrachloroethane. The NJ Superior Court has ordered the implementation of a remedial action involving groundwater recovery in conjunction with the installation of a slurry wall and rerouting of Pricketts Brook, which flows through the CPS and Madison facilities.

Since the first detection of contaminants in groundwater in 1970, numerous investigations have been conducted to define the source, nature, and extent of contamination and to characterize the site hydrogeology. Although a general understanding of the physical characteristics of the site and the nature, extent, and observed fate and transport of contaminants in groundwater can be derived from the previous investigations, understanding of the site is limited by the informational deficiencies of the previous investigations.

Site geology is characteristic of the northern Coastal Plain physiographic province where unconsolidated sediments (i.e., clay, silt, sand, and gravel) overlie a bedrock surface. The uppermost geologic unit (the Old Bridge Sand) constitutes a major unconfined aquifer. A clay layer, the Woodbridge Clay, serves as a basal confining layer for the Old Bridge Aquifer. Data indicate that at least in certain areas the entire thickness of the Old Bridge Aquifer has been contaminated.

Based on a selected number of monitoring wells for which well construction and analytical data are available, groundwater flow patterns and the extent of contamination in 1982 and 1988 were delineated. In general, groundwater flows southwest. The shape of the contaminant plume corresponds to a contaminant source located at the operating areas of CPS and Madison and laterally extended southwest in the general direction of groundwater flow. The downgradient extent of the contaminant plume appears to be controlled by Pricketts Pond.

give flow maps

Comparison of contaminant concentrations measured in 1982 and 1988 indicates that the concentrations of zinc, lead, and cadmium have decreased since 1982 and that the zinc, lead, and cadmium plumes are less laterally extensive. The decrease of metal concentrations in groundwater may be explained by groundwater withdrawal from well MI-T1, which is located in the vicinity of the greatest reduction of metal concentrations. Further information on this pumping well is necessary to verify this correlation. There appears to be no net gain or loss of TVOC in the groundwater system between 1982 and 1988; however, the TVOC plume has increased in extent in the downgradient direction. Based on these observations and assuming that flow conditions remain the same, the fate and transport of the contaminants present in groundwater should continue to follow trends similar to those observed between 1982 and 1988.

The baseline risk assessment indicates that the potential exists for adverse noncarcinogenic effects following hypothetical exposure to groundwater from the CPS/Madison site. The HI for combined exposure across chemicals is calculated at approximately 21. The excess lifetime cancer risk was estimated for hypothetical exposure to mean levels of potential carcinogens in the groundwater downgradient from the CPS/Madison site. The

excess cancer risk to the maximally exposed individual was determined to be approximately 1.6×10^{-3} .

1.8 DATA LIMITATIONS AND RECOMMENDATIONS FOR FURTHER STUDY

1.8.1 Pump Test(s)

The cone of depression, which develops as a result of pumping a well, expands more slowly in an unconfined aquifer, such as the Old Bridge Aquifer, than in most confined aquifers. An average pumping period for an aquifer test in a confined aquifer is 24 hours. Pump tests conducted in unconfined aquifers typically last 48 hours (Driscoll 1986). The pumping period is particularly critical in order to detect effects that can be observed in time-drawdown data due to boundaries (geologic or hydraulic) that limit recharge to a pumping well. Time-drawdown data collected during a pumping test of MI-T1 (see Figure 1-3--Well Location Map) indicate that an increase in the rate of drawdown occurred near the end of the 24-hour duration pump test, suggesting a boundary influence (CH2M Hill 1984). It is recommended that future pump tests be conducted over a longer pumping period to accurately predict or define the type of boundary conditions that may exist in the subsurface and that could affect the migration of contaminants.

1.8.2 Groundwater Flow Modeling

The location, number, and pumping rate of the pumping wells in the vicinity of the site could affect groundwater flow patterns significantly. Groundwater modeling should be used to predict variations in the groundwater flow resulting from groundwater withdrawal at the various production wells in the vicinity of the CPS/Madison site. This type of evaluation is particularly important when addressing the regional impact of

pumping wells on saltwater intrusion and the local migration of contaminants.

1.8.3 Identification of Recharge and Discharge Areas

Recharge and discharge areas must be defined to assist in accurately predicting contaminant migration. In addition, the placement of a slurry wall should correspond to natural discharge areas in order to maximize the effectiveness of a groundwater recovery system and to minimize the effects to the natural flow patterns. It is recommended that additional staff gauge data be collected, specifically around the southeastern edge of Pricketts Pond, in order to define the hydraulic connection between the Pond and the surrounding groundwater.

1.8.4 Additional Soil Sampling and Testing

The limited data available from previous investigations suggest that the soils in the study area are contaminated. A comprehensive sampling and analysis program should be conducted in the study area to determine whether the soils will continue to contaminate the groundwater system. Specifically, (1) soils beneath the paved area on the CPS/Madison facilities must be sampled, (2) the leachability of contaminants in the soil should be analyzed, (3) the extent of contamination in the soils should be defined, and (4) quantitative measurements of soil properties (e.g., infiltration rates) should be made.

1.8.5 Additional Monitoring, Sampling, and Testing of Surface Water and Sediments

Analysis of surface runoff entering Pricketts Brook is suggested to determine the entry points, quantity, and quality of the surface runoff before it reaches Pricketts Brook. In addition, the effectiveness and design of the engineered

catchment structures (e.g., berms or ditches) should be identified to determine their impact on the distribution of surface runoff originating from the CPS and Madison operating areas.

1.8.6 Additional Groundwater Monitoring and Sampling

Additional groundwater sampling is necessary to determine the downgradient extent of zinc, cadmium, and TVOC in groundwater. Additional rounds of water level measurements are necessary to further delineate or identify (1) surface-water and groundwater interactions, (2) effects of pumping wells, (3) seasonal changes in flow patterns, and 4) the apparent upward vertical gradients in the eastern portion of the study area.

1.8.7 Demographic and Ecological Investigations

The following information should be obtained from a thorough demographic and ecological investigation of the area: (1) the sensitivity of the surrounding populations, (2) water quality and stream classifications of Pricketts Brook watershed, (3) actual use of the waters in the Pricketts Brook watershed, (4) identification of the fauna and flora that are supported by the surrounding wetlands, (5) identification of endangered species, and (6) specifics (e.g., identification of species) regarding the dead trees and shrubs adjacent to the site.

1.8.8 Well Integrity Evaluation Program

An extensive effort should be made to clarify the integrity of the wells monitoring the site. Well installation and construction standards have changed significantly over the past 20 years and many older wells may not be constructed adequately by today's standards. In addition, even if the construction of

the older wells is satisfactory, the specifications of these wells may differ significantly from the more recently installed wells. For example, wells can differ in screened interval and screened length and as a consequence, may not allow the collection of equivalent or representative groundwater samples. By reviewing well records, the differences between wells can be defined and used to explain inconsistencies in water quality and water levels. For instance, pumping wells that were sampled during previous investigations may have been screened in more than one aquifer and therefore, may represent the average water quality of two aquifers.

A well integrity evaluation program should include an analysis of the following:

- Well construction and design details
 - Date/time of construction
 - Drilling method and drilling fluid
 - Well location (surveyed location)
 - Bore hole diameter and well casing diameter
 - Well depth
 - Drilling and lithologic logs
 - Casing materials
 - Screen materials and design
 - Casing and screen joint type
 - Screen slot size/length
 - Filter pack material/size, grain analysis
 - Filter pack volume calculations
 - Filter pack placement method
 - Sealant materials (percent bentonite)
 - Surface seal design/construction
 - Well development procedures
 - Type of protective cap
 - Ground surface elevation
 - Surveyor's pin elevation on concrete apron
 - Top of monitoring well casing elevation
 - Top of protective steel casing elevation
 - Detailed drawing of well

- Well tests
 - Water-level measurements before, during, and after drawdown tests (slug or pump tests)
 - Pumping rate or rates
 - Interpretation of test results
- Pumping well information
 - Type of pump
 - Depth to the pump intake
 - Pump's performance and efficiency data
 - Length of air line or a description of facilities provided for water-level measurements
 - Description of measuring point
 - Type of meter used to measure the flow rate
 - Weekly readings of the flow-meter dial
 - Weekly measurements of the static and pumping water levels
 - Record of well maintenance
- Record of well abandonment
 - Date well was discontinued
 - Description of the methods and materials used to seal or plug the well.

1.8.9 Verification of Analytical Results

Analytical methods and quality assurance/quality control procedures must be evaluated for all analytical results in order to identify data of questionable validity.

1.8.10 Offsite Source Investigation

Offsite sources of contamination, in particular the Evor Phillips Superfund site, should be investigated to determine the effect these potential contaminant sources have had or will have on groundwater at the CPS/Madison site. A water level contour map should be constructed that includes wells located at all potential offsite sources and adjacent well fields. Groundwater quality data should be evaluated for offsite sources that are determined to be upgradient of the CPS/Madison site.

1.8.11 Indicator Chemicals

The contaminants that have been used as indicators of the extent of contamination at the CPS/Madison site should be re-evaluated. Specifically, indicator contaminants should be chosen based on their concentration in all effected media (i.e., soils, surface water, sediments, and groundwater), the nature of the original contaminant source, and the specific chemical properties (e.g., toxicity, solubility, and density) of the indicator contaminants.

Because contaminated groundwater may percolate down an inadequately sealed annular space, existing monitoring wells should also be evaluated to ensure that they are not contributing to the contamination of deeper aquifer zones.

This was not done for this report?

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2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This chapter presents the development of remedial action objectives, the identification of the universe of technologies with the potential to achieve the remedial action objectives, and the screening of these technologies for possible consideration in the development of remedial alternatives in Chapter 3.

From the available information and data presented and evaluated in Chapter 1, the following factors have been identified as governing the scope and approach for identifying feasible and effective remedial action alternatives for the CPS/Madison site.

- This Feasibility Study (FS) will only address the operable unit--contaminated groundwater.
- The confining layer (South Amboy Fire Clay) between the Old Bridge Aquifer (upper aquifer) and the Farrington Aquifer (lower aquifer) is assumed to be significant for the purpose of this evaluation (i.e., cleanup of the upper aquifer will be the main focus of the FS). This assumption should be verified as part of the predesign activities.
- Groundwater sampling data, contained in the Wehran report (1989), are the basis for defining the extent of contamination in the Old Bridge Aquifer.

Based on the Wehran report (1989), contamination in the Old Bridge Aquifer consists of approximately 30 organics and 4 heavy metals in a plume, extending from the CPS/Madison plant site and discharging from shallow groundwater into Pricketts Pond.

2.1 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

Remedial action objectives are comprised of target cleanup levels and other remediation criteria. Currently, two U.S. Environmental Protection Agency (EPA) documents provide the most

Soils will address in a Subsequent FS.

detailed overview of methods for derivation of cleanup levels for site remediation--the Superfund Public Health Evaluation Manual (SPHEM [USEPA 1986]) and the Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites (USEPA 1988). Based on these documents and the additional guidance presented in the Remedial Investigation/FS Guidance Document (USEPA 1988b) and the revised National Contingency Plan (NCP 1988), the approach to the derivation of remediation goals consists of:

- Identifying subject/indicator chemicals of concern
- Assembling a listing of all available applicable or relevant and appropriate requirements (ARARs)
- Identifying potential exposure pathways and receptors at risk
- Developing exposure scenarios and characterizing environmental concentrations at the points of exposure using available monitoring data and/or the results of environmental fate modeling
- Evaluating the overall protectiveness to human health from exposure to chemicals at ARAR levels, if ARARs are available for all subject chemicals (the combined exposure across chemicals and multiple pathways must be considered)
- Adopting ARAR levels as remediation goals (target cleanup levels) if they are found to be protective
- Deriving target cleanup levels based upon the results of risk assessment if ARARs are not available for all subject chemicals or are not found to be protective of human health.

This approach was followed during the development of remediation objectives for contaminated groundwater at the CPS/Madison site. In the following sections, a detailed discussion of all methods employed and the results of the assessment are presented.

should
It is important to recognize that the derivation of remediation objectives becomes a complex process for any site with numerous contaminants and/or multiple exposure pathways for which ARARs are not available or are not protective of human health. Under these circumstances, the development of cleanup levels must incorporate all elements of a comprehensive risk assessment. In essence, an acceptable target risk level is first established for the combined exposure across chemicals and environmental media. Using the risk assessment methods established by EPA, the corresponding acceptable levels of each subject chemical are then back-calculated for the affected environmental media.

The chemical-specific cleanup levels derived by the risk assessment methods cannot be considered absolute targets for site remediation. Rather, these risk-based guidelines, once developed, are used in conjunction with the results of the analysis of engineering feasibility and implementation costs to refine the remediation goals. The overall objective is to develop cleanup levels that are protective of human health, technically sound, and cost-effective. As noted previously, a target risk range must be established and achieved for selected remedial alternatives. There is considerable latitude inherent in the process of apportioning risk across chemicals and exposure pathways, however.

2.1.1 Deriving Target Cleanup Levels

As explained in Chapter 1, remediation objectives have been developed for 13 contaminants in groundwater downgradient of the CPS/Madison site. This subset of the total mix of chemicals found in the 1982 and 1988 sampling studies has been selected based on the results of the baseline risk assessment.

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The 13 chemicals selected comprise, respectively, 99 and 98 percent of the projected baseline carcinogenic and noncarcinogenic risk to human health. The chemicals of interest are:

- Cadmium
- Lead
- Zinc
- Benzene
- Carbon tetrachloride
- 1,1-dichloroethane
- 1,2-dichloroethane
- 1,2-dichloropropane
- Hexachlorobenzene
- Hexachlorobutadiene
- Methylene chloride
- Trichloroethylene
- Vinyl chloride.

Table 2-1 presents the contribution of each chemical found in groundwater (PAS 1982 and Wehran 1989) to the overall baseline risk estimates.

In general, if ARARs are not available for all subject chemicals or are not protective for combined exposure across chemicals (e.g., the excess lifetime cancer risk is not within the acceptable range), EPA recommends the use of risk assessment to derive remediation goals for each chemical under evaluation. EPA regulations still require compliance with ARARs for those chemicals for which ARARs exist. It may be necessary to set remediation goals at levels more stringent than ARAR limits, however. The revised NCP clearly addresses this issue:

In general, chemical-specific ARARs are set for a single chemical or closely related group of chemicals. These requirements typically do not consider the mixtures of chemicals and other conditions (e.g., multiple pathways of exposure) that may be found at CERCLA sites. Therefore, due to site-specific factors, remediation goals set at the level of single chemical-specific requirements [i.e.,

TABLE 2-1. DERIVATION OF TARGET CLEANUP LEVELS: RISK APPORTIONMENT

Chemical	Mean (a) Concentration in Groundwater (ug/L)	Hazard Index for Chronic Exposure (Dose/RfD)	Percent of Combined Hazard Index	Excess Lifetime Cancer Risk (Dose x q1*)	Percent of Combined Excess Lifetime Cancer Risk
INORGANICS					
Cadmium	76.15	4.35E+00	20.768%		
Copper	871.96				
Lead	56.80	1.16E+00	5.532%		
Zinc	25398.00	3.63E+00	17.316%		
ORGANICS					
Acenaphthene	1.10				
Acenaphthylene	2.19				
Benzene	15.10			2.50E-05	1.600%
Bis(2-ethylhexyl)phthalate	21.76	3.11E-02	0.148%	8.70E-06	0.556%
Bromoform	9.45				
Carbon Tetrachloride	133.15	1.09E+01	51.873%	9.89E-04	63.225%
Chlorobenzene	46.13	1.26E-01	0.599%		
Chloroform	25.48	1.46E-01	0.695%	8.88E-06	0.568%
Chloromethane	0.31				
Chrysene	1.14				
1,3-Dichlorobenzene	1.00	1.43E-04	0.001%		
1,4-Dichlorobenzene	1.00	1.43E-04	0.001%	1.37E-06	0.088%
1,2-Dichloroethane	31.29	1.49E-02	0.071%	1.63E-04	10.399%
1,1-Dichloroethane	5.55	2.64E-03	0.013%	2.89E-05	1.845%
1,2-Dichloroethylene	18.27				
1,2-Dichloropropane	6.56			2.55E-05	1.629%
Dimethylphthalate	5.67				
Ethylbenzene	7.98	4.56E-03	0.022%		
Hexachlorobenzene	2.52	9.01E-02	0.430%	1.23E-04	7.833%
Hexachlorobutadiene	3.48	9.93E-02	0.474%	1.55E-05	0.990%
Hexachlorocyclopentadiene	8.76	3.58E-02	0.171%		
Methylene Chloride	261.45	2.49E-01	1.188%	1.12E-04	7.163%
N-Nitrosodiphenylamine	23.57			3.30E-06	0.211%
1,1,2,2,-Tetrachlorethane	1.83				
Tetrachloroethylene	0.70	4.00E-03	0.019%	2.04E-06	0.130%
Toluene	54.39	1.04E-02	0.049%		
1,1,1-Trichloroethane	54.20	3.44E-02	0.164%		
Trichloroethylene	16.99	9.71E-02	0.463%	1.07E-05	0.683%
Vinyl Chloride	0.37			4.82E-05	3.081%
Xylenes	16.37	4.68E-04	0.002%		

Hazard Index: Combined Exposure		2.10E+01	100.00%		
Excess Lifetime Carcinogenic Risk: Combined Exposure				1.56E-03	100.00%

a. Arithmetic mean of combined data set sampled 3/82 (PAS 1982) and 11/14-16/88 (Wehran 1989). "Not detected" results were treated as 0.0 and included in the calculation of the mean.

ARARs] may not adequately protect human health or the environment at that site. In these instances, remediation goals may be set below the chemical-specific requirements (i.e., at more stringent levels) in order to obtain a remedy that is protective.

EPA considers an excess lifetime risk of 10^{-7} to 10^{-4} acceptable for combined exposure to carcinogens. The 10^{-6} risk level is recommended by EPA as a benchmark or "point of departure" in risk assessment and risk management of hazardous waste sites (USEPA 1986, USEPA 1988, and Smith and Zamuda 1988). The target risk level may be adjusted on a site-specific basis to a higher or lower level.

Factors that are considered in adjusting the target risk level include: (1) sensitivities of the population at risk or other nonsite-related health risks, (2) the effects on nonhuman receptors, (3) the weight of evidence (uncertainty) of toxicity information, (4) the potential for actual exposure, and (5) the ability to detect or monitor the chemicals under evaluation. Technical feasibility and cost effectiveness may also be considered in adjusting the target risk level.

EPA recognizes that there are a number of ways to apportion the total risk level across chemicals and then to calculate the corresponding concentrations that serve as remediation goals (USEPA 1986). In SPHEM, EPA offers two simple approaches for consideration. The first method involves dividing the target carcinogenic risk level by the number of subject chemicals that are potential carcinogens for a single exposure pathway. Once the target risk is determined for each chemical, the target cleanup levels in the environment are back-calculated, given the chronic daily intake and the carcinogenic potency factors. EPA notes that this approach is simple and conservative, ensuring that the target risk will not

be exceeded if the target intakes are attained. The Agency acknowledges, however, that this may not necessarily result in the most efficient or cost-effective technical design.

The second approach suggested by EPA is to allow one or two chemicals to drive the design process. For example, one or two compounds may be particularly difficult to treat or may be a highly potent carcinogen. Cleanup levels for these chemicals might need to be extremely low so that the total risk falls within the established target risk range. Therefore, by designing remedial alternatives to reduce environmental concentrations of these chemicals to within the target range, levels of the other subject chemicals may become negligible by default. Treatment design would be refined so that combined exposures from the various routes achieve target cleanup levels (or fall within a target risk range). These adjustments would be made based on an understanding of the exposure pathways of greatest risk and the most cost-effective design alternatives.

The first EPA-recommended method to apportion risk across subject chemicals was used for this FS. In developing target cleanup levels for the CPS/Madison site, the combined excess lifetime carcinogenic risk (i.e., for all chemicals present and all exposure routes) should be less than 1×10^{-4} . Therefore, the excess risk for any given chemical must be approximately (1×10^{-4}) divided by 13.

Table 2-2 lists the target cleanup levels derived for the selected chemicals. Federal and State ARARs have been used in selecting cleanup levels as well as risk-based concentrations. As the table shows, the combined excess lifetime cancer risk of the hypothetical exposure to chemicals in groundwater at the proposed levels is approximately 8×10^{-5} . The combined hazard index is approximately 1.6. Given the very conservative

TABLE 2-2. DERIVATION OF TARGET CLEANUP LEVELS: REMEDIATION OBJECTIVES

Chemical	Proposed Remediation Goals for Groundwater (a) (ug/L)	Hazard Index for Chronic Exposure (Dose/RfD)	Excess Lifetime Cancer Risk (Dose x q1*)
INORGANICS			
Cadmium	10.00 b	5.71E-01	
Copper			
Lead	5.00 c	1.02E-01	
Zinc	5000.00 d	7.14E-01	
ORGANICS			
Acenaphthene			
Acenaphthylene			
Benzene	1.00 e		1.66E-06
Bis(2-ethylhexyl)phthalate			
Bromoform			
Carbon Tetrachloride	2.00 e	1.63E-01	1.49E-05
Chlorobenzene			
Chloroform			
Chloromethane			
Chrysene			
1,3-Dichlorobenzene			
1,4-Dichlorobenzene			
1,2-Dichloroethane	2.00 e	9.52E-04	1.04E-05
1,1-Dichloroethane	2.00 e	9.52E-04	1.04E-05
1,2-Dichloroethylene			
1,2-Dichloropropane	2.57 f		1.00E-05
Dimethylphthalate			
Ethylbenzene			
Hexachlorobenzene	0.21 f	1.47E-02	1.00E-05
Hexachlorobutadiene	2.24 f	6.41E-02	1.00E-05
Hexachlorocyclopentadiene			
Methylene Chloride	2.00 e	1.90E-03	8.57E-07
N-Nitrosodiphenylamine			
1,1,2,2-Tetrachlorethane			
Tetrachloroethylene			
Toluene			
1,1,1-Trichloroethane			
Trichloroethylene	1.00 e	5.71E-03	6.29E-07
Vinyl Chloride	0.10 f		1.31E-05
Xylenes			
Hazard Index: Combined Exposure		1.64E+00	
Excess Lifetime Carcinogenic Risk: Combined Exposure			8.19E-05

- a. Remediation goals were established based on a review of Federal and State ARARs, and a risk-based evaluation of the overall "protectiveness" of combined exposure across chemicals. Cleanup levels have been proposed for 13 chemicals. The compounds comprise greater than 99 and 98 percent of the overall carcinogenic and noncarcinogenic risk estimated in the baseline assessment (see Table 2-1).
- b. EPA primary drinking water standard
- c. Proposed MCL for lead. FR August 1988
- d. Secondary maximum contaminant level. No Federal or State MCL is available.
- e. New Jersey drinking water standard.
- f. Risk-based remediation goal corresponding to the 10-5 excess lifetime cancer risk level.

assumptions used in the exposure assessment and risk characterization, a hazard index of 1.6 is considered acceptable and indicates that the proposed cleanup levels are protective against adverse noncarcinogenic effects.

If the proposed target cleanup levels are achieved for the 13 selected compounds, groundwater downgradient of the CPS/Madison facility will comply with available ARARs and the overall risks to human health will be acceptable.

2.1.2 Developing Remediation Criteria

Remediation criteria were developed by assessing the potential for exposure to contaminants of concern and evaluating the associated risks to human health and the environment. The criteria are based on the following:

- Contaminants of interest present in the Old Bridge Aquifer that will be addressed through remediation activities are: cadmium, lead, zinc, benzene, carbon tetrachloride, 1,1-dichloroethane, 1,2-dichloroethane, 1,2-dichloropropane, hexachlorobenzene, hexachlorobutadiene, methylene chloride, trichloroethylene, and vinyl chloride.
- The extent of contamination is represented by the isoconcentration plots of cadmium, lead, zinc, and total volatile organic compounds (TVOCs [presented and discussed in Section 1.4]). The analysis indicates that cadmium, zinc, and lead plumes have decreased and centralized over the west end of the Madison property. Cadmium and zinc isoconcentration maps indicate that either Pricketts Pond may be associated with a preferential pathway of contaminant migration or that Pricketts Pond may act, or may have acted, as a contaminant source. The highest TVOC contaminant concentrations occur at the south eastern corner of the Madison Industries property, with concentrations decreasing slightly cross-gradient toward the north eastern portion of Pricketts Pond. (The available data did not support an analysis of the extent of individual organic contaminant migration. In lieu of such data, TVOC was used as a surrogate parameter.)

- In general, groundwater flow at the CPS/Madison site is southwest. The water table in the Old Bridge Sand ranges from approximately 0 to 5 feet. The Old Bridge Sand is separated from the lower Farrington Sand Aquifer by approximately 120 feet of clays, silts, and sands of the discontinuous South Amboy Fire Clay and Sayerville Sand units, and the more laterally continuous and impermeable Woodbridge Clay (Dames and Moore 1980). During the development of this FS, no information was available on the hydraulic connection between the Old Bridge and Farrington Sand Aquifers. For the purpose of this FS, it is assumed that the South Amboy Fire Clay is a substantial and continuous layer.

Saltwater intrusion has been documented in both the Farrington and Old Bridge Aquifers. Several reports have indicated that over pumpage of the Old Bridge Aquifer could induce saltwater intrusion into the Aquifer.

(Site characteristics that affect the transport and transformation of contaminants [presented in detail in Section 1.3 and 1.5]).

- Pathways for exposure and exposure risk assessment, are presented in Section 1.6. The baseline risk assessment calculated hypothetical (protective) risks based on human ingestion exposure to chemicals in solution and volatile compounds released during showering and other indoor uses of groundwater. Both carcinogenic and noncarcinogenic risks were assessed. Under the hypothetical scenario, the hazard index for combined exposure across contaminant compounds was approximately 21, while the excess lifetime cancer risk for a maximally exposed individual was determined to be approximately 1.6×10^{-3} .

The remediation criteria for the management of the contaminated plume migration include: (1) preventing or further limiting the migration of contaminants beyond their current extent, (2) eliminating or minimizing the threat posed to public health and the environment from the current extent of contamination, and (3) managing migration actions to reduce the risk to public health and the environment.

2.1.2.1 Preventing or Further Limiting the Migration of Contaminants Beyond Their Current Extent

Preventing and/or limiting the migration of contaminants beyond their current extent requires the identification of contaminant transport pathways. These pathways include further transport via groundwater flow with subsequent discharge to surface water, including Pricketts Brook, Pricketts Pond, and eventually to the Raritan River, or transport via groundwater flow to the Perth Amboy water supply wells, which are approximately 2,000 feet downgradient of the current extent of the groundwater plume (Wehran 1989). If allowed to reach the water supply wells, the contaminants could be transported directly to human receptors for ingestion or inhalation of vapors.

2.1.2.2 Eliminating or Minimizing the Threat Posed to Public Health and the Environment From the Current Extent of Contamination

The groundwater from the contaminated plume is not currently used as a public water supply. Therefore, the current risks to public health and the environment by contaminated groundwater are minimized. Meeting this objective, however, requires the evaluation of contaminated groundwater as a source of drinking water and as a source of contamination in receiving surface waters. This evaluation was conducted in the Evaluation of Baseline Risk (Chapter 1) and is quantified in Table 2-1. Once the threat is defined, the incremental improvement achieved by the remedial action alternatives can be identified and a comparison of alternatives made.

2.1.2.3 Managing of Migration Actions to Reduce Risk

There are two general types of management of migration actions that may be adopted to reduce the human health and environmental risks associated with exposure to the contaminated groundwater or exposure to contaminants that have migrated from the groundwater to other media. The management types involve:

- Restricting the use of or isolating groundwater to reduce or eliminate the potential for exposure
- Reducing contaminant levels in the groundwater via extraction and treatment.

Table 2-3 presents a summary of remedial action objectives, general response actions, technology types, and process options used in the development and screening of technologies. This table is organized so that broad remedial action objectives are initially provided, with increasingly detailed approaches for addressing these objectives as the table is read from left to right. For example, to address the remedial action objectives using plume diversion, three general remedial technology types and eight, more-detailed process options are provided.

A definition and brief discussion of process options are provided in Appendix B.

2.2 GENERAL RESPONSE ACTIONS

General response actions for the Old Bridge Aquifer are shown in Table 2-3. General response actions represent the universe of technologies that have the potential to satisfy the remedial response objectives developed in Section 2.1. General response actions include: no action, plume diversion

TABLE 2-3. SUMMARY OF REMEDIAL ACTION OBJECTIVES, GENERAL RESPONSE ACTIONS, TECHNOLOGY TYPES, AND PROCESS OPTIONS

Environmental Media	Remedial Action Objectives	General Response Actions	Remedial Technology Types	Process Options
Groundwater	Prevent or limit further migration of contaminants; eliminate or minimize current health and environmental threats	<u>No-Action/Institutional Actions</u>	<u>No-Action/Institutional Technologies</u>	
	Prevent ingestion of water or inhalation of water vapors in excess of a total cancer risk of 8×10^{-5} and a combined hazard index (HI) of 1.6.	<ul style="list-style-type: none"> o No action o Institutional action o Alternate water supply o Monitoring 	<ul style="list-style-type: none"> o Site security o Land use restrictions o Alternate water supply o Monitoring 	<ul style="list-style-type: none"> o Security fencing, berms, no change of drinking water sources o Signs, deed restrictions o Change of drinking water sources o Additional monitoring
	Objectives attained by:	<u>Plume Diversion Actions</u>	<u>Plume Diversion Technologies</u>	
	<ul style="list-style-type: none"> o Restricting use of or isolating groundwater to eliminate all potential for exposure o Reducing contaminant levels o Removing groundwater (for treatment or disposal elsewhere). 	<ul style="list-style-type: none"> o Plume diversion 	<ul style="list-style-type: none"> o Hydrologic barriers o Vertical barriers o Horizontal barriers below contamination o Relocation of Pricketts Brook 	<ul style="list-style-type: none"> o Injection wells o Soil-bentonite slurry walls, cement-bentonite slurry walls, grouting/grout curtains, sheet pile walls, vibrating beam emplacement o Grout injection, block displacement
		<u>In Situ Treatment Actions</u>	<u>In Situ Treatment Technologies</u>	
		<ul style="list-style-type: none"> o In situ treatment 	<ul style="list-style-type: none"> o Biological o Chemical 	<ul style="list-style-type: none"> o Biodegradation o Chemical reaction, permeable treatment beds
		<u>Collection/Treatment/Disposal Actions</u>	<u>Collection Technologies</u>	
		<ul style="list-style-type: none"> o Collection 	<ul style="list-style-type: none"> o Pumping o Subsurface drains 	<ul style="list-style-type: none"> o Remediation wells o Interceptor trenches

TABLE 2-3. SUMMARY OF REMEDIAL ACTION OBJECTIVES, GENERAL RESPONSE ACTIONS, TECHNOLOGY TYPES AND PROCESS OPTIONS (Continued)

Environmental Media	Remedial Action Objectives	General Response Actions	Remedial Technology Types	Process Options
Groundwater (continued)		<u>Collection/Treatment/Disposal Actions (continued)</u>	<u>Onsite Treatment Technologies</u>	
		o Treatment	o Onsite treatment	o RCRA/TSCA type facility
			o Biological degradation	o Activated sludge, fixed film systems, PACT treatment, aerobic lagoons, mutant bacteria, land treatment, aerobic composting, anaerobic digestion, trickling filters, fluidized bed reactor
			o Chemical treatment	o Hydrolysis, UV oxidation, reduction/oxidation, precipitation, coagulation, neutralization, UV/ozonation, chemical dechlorination, flocculation
			o Physical remediation	o Sorption, air stripping, steam stripping, distillation, thin film evaporation, liquid-liquid solvent extraction, liquid-gas solvent extraction, reverse osmosis, ultrafiltration, electrodialysis, freeze crystallization, flotation, ion exchange, sedimentation/clarification/gravity thickening
			o Thermal destruction	o Liquid injection incinerator, industrial furnace, multiple hearth incinerator, fluidized bed incinerator, pyrolysis, fluidized wall incinerator
		<u>Disposal</u>	<u>Disposal/Discharge Technologies</u>	
			o Onsite treatment disposal	o POTW, deep well injection, reinjection wells, surface streams onsite
			<u>Offsite/Treatment/Disposal/Discharge Technologies</u>	
			o Offsite discharge	o Streams offsite
			o Offsite/treatment/disposal	o RCRA/TSCA permitted facility

actions, and collection/treatment/disposal actions. For each general response action identified, there is one or more specific response actions identified in Table 2-3. For example, a no-action/institutional general response category includes four applicable, alternative response actions--no action, institutional action, alternate water supply, and monitoring.

In addition, each general action has at least one technology, and for each technology, at least one process option. Process options will be combined when developing alternatives for eventual screening and detailed analysis.

2.3 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

The purpose of the initial screening of technologies is to eliminate general response actions, remedial technologies, or process options that do not provide a permanent means to prevent or minimize the release of hazardous substances or cannot be implemented as a result of site-specific conditions. (See Appendix B for definitions and a brief discussion of remedial technologies and process options.)

The criteria used in the initial screening step include:

- Compatibility of a treatment process with the chemicals of concern
- Ability of a process to treat a wide range of chemicals
- Volume and character of wastes generated by the process
- Physical and chemical/biochemical stability of the process at extreme temperatures.

These criteria do not include the evaluation of option effectiveness or ease of implementation, which are examined in detail in Chapter 3.

Table 2-4 presents the initial screening of technologies, which addresses the general response actions for the management of migration actions for groundwater. In this table, different remedial technology types have been identified for each of the general response actions. For each technology type, a list of different process options is provided. A brief description for each process option, including comments concerning elimination or selection for future evaluation, is also provided.

For each of the media of interest, a no-action general response is included in the initial screening. This alternative provides the baseline for comparison with other responses. An analysis of the no-action response is required under the NCP.

Potentially applicable technologies and process options for migration control are selected on the basis of effectiveness to remove the contaminants of concern and reduce the volume of hazardous material, and technical implementability. For example, for the plume diversion general response action, the remedial technology of vertical barriers meets the screening criteria; slurry walls are the process option of choice. Therefore, the general response action, remedial technology (vertical barriers) and process option (slurry walls) are highlighted in the table.

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES

Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
No-Action/ Institutional Actions	Site Security	Fencing, etc.	Fences, signs surrounding sites.	Not applicable because it covers both public and private areas. Very little, if any, exposure is expected on site due to paved areas.
	Access Restrictions	Deed Restrictions	Deeds for property in the area of influence could include restriction on wells.	Not applicable because the extent of contamination is not completely known.
	Alternate Water Supply	River Water Supply	Provide water supply from surface waters.	Not applicable because the extent of contamination is not completely known.
		New Wells	New water supply wells in areas outside the contaminated plume.	Not applicable because the extent of contamination is not completely known.
Plume Diversion	Monitoring	Groundwater Monitoring	Ongoing monitoring of downgradient wells.	Potentially applicable.
	Hydrologic Barriers	Injection Wells	Injection of water via well arrays to force diversion of contaminant plume.	Not applicable due to generation of alternate contamination problems.
	Vertical Barriers	Slurry Walls	Trench around areas of contamination and fill with a soil (or cement) bentonite slurry.	Potentially applicable.
		Diaphragm Walls	Poured or pre-cast reinforced concrete panels.	Not applicable/necessary because there are no special requirements for structural strength.
		Relocation of Pricketts Brook	Construction of a 3,000 foot long by 35 foot wide channel south of stream bed and existing stream bed.	Potentially applicable.

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

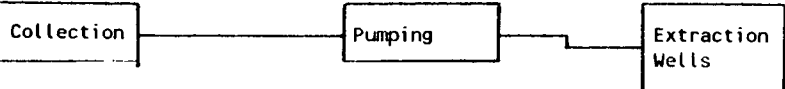
Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Plume Diversion (continued)	Vertical Barriers (continued)	Grout Curtains	Subsurface barriers created by pressure injecting grout in a regular pattern of drilled holes.	Not applicable because proper grout selection is based on physical and chemical properties of the soil or rock strata and its compatibility with all chemicals in the groundwater; information that is not available at the present time.
		Sheet Pile Walls	Interlocking panels of steel, concrete, or wood installed to form a barrier.	Not applicable--wood is an ineffective water barrier, concrete is used where structural strength is required; steel corrosion is a potential problem.
		Vibrating Beam	Vibrating force to advance beams into ground with injection of slurry as beam is withdrawn.	Not applicable because of the possibility of incomplete joining or overlapping of injected slurry, which would result in less-effective diversion.
		Grout Injection	Pressure injection of grout through a pattern of drilled holes across the site.	Not applicable because of the possibility of incomplete joining or overlapping of injected grout, which would result in ineffective diversion.
	Horizontal Barriers Below Contamination	Block Displacement	Along with vertical barriers, injection of group in notched injection holes.	Not applicable because of the difficulty in verifying that continuity is achieved.
			Series of wells to extract contaminated groundwater.	Potentially applicable.

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Collection (continued)	Pumping (continued)	Extraction/ Injection Wells	Injection wells inject uncontaminated groundwater and direct flow towards extraction wells.	Not applicable because it is not necessary to direct flow towards extraction sites.
	Subsurface Drains	Interceptor Trenches	Perforated pipe in trenches back-filled with porous media to collect contaminated water.	Not applicable due to greater costs over extraction wells and increased exposure risks to workers.
Treatment	Biological Degradation	Activated Sludge Reactors	Degradation of organics using microorganisms in an aerobic environment.	Not applicable because of potential for disruption of process due to high metals concentrations, lack of nutrients to maintain activity of microorganisms, relatively low and variable organics concentrations.
		Trickling Filters	Degradation of organics in an aerobic environment by microorganisms attached to media in a packed bed.	Not applicable because of potential for disruption of process due to high metals concentrations, lack of nutrients to maintain activity of microorganisms, relatively low and variable organics concentrations.
		Fixed Film Systems (rotating biological disks)	Aerobic degradation of organics by microorganisms attached to rotating media.	Not applicable because of potential for disruption of process due to high metals concentrations, lack of nutrients to maintain activity of microorganisms, relatively low and variable organics concentrations.

Where is rest p 23

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (continued)	Chemical Treatment (continued)	UV/Ozonation	Ozone with UV light used as catalytic agent for oxidation and trace organic removal.	Not applicable due to generation of secondary wastes, selective oxidation of certain compounds, and need for a continuous ozone supply.
		Chemical Dechlorination	Chlorine used as an oxidizing agent followed by dechlorination by reaction with a reducing agent.	Not feasible since it has very limited applicability and may not be suitable for all the organics in the water.
	Physical Treatment	Sedimentation/Clarification/Gravity Thickening	Clarifier or sedimentation tanks used to promote settling and removal of precipitated flocs.	Potentially applicable only if precipitation/coagulation/flocculation are used.
		Filtration	Granular media used to filter suspended solids and colloids.	Applicable to any treatment process to protect it against fouling.
		Carbon Adsorption	Selective adsorption of contaminants by activated carbon.	Potentially applicable.
		Ion Exchange/Sorptive Resins	Ion exchange (cations or anions) between the resin and water--sorptive resins can be used where the removal mechanism is one of sorption rather than ion exchange.	Cation exchange resins potentially applicable to remove the metal contaminants.
		Air Stripping	Large volumes of air come in contact with water usually in a countercurrent flow configuration to strip VOCs from water.	Potentially applicable as a treatment method for the VOCs in the groundwater.
		Steam Stripping	Same removal process as air stripping but with steam as the removal medium. Appropriate for the more soluble volatile organic fraction in water.	Not applicable because steam-stripping costs will be substantially higher than biological or other physical treatment methods for dissolved organics.

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (continued)	Physical Treatment (continued)	Distillation	Constituent blends are separated based on volatility differences.	Not applicable due to substantially higher costs over other physical treatment methods.
		Dissolved Air Flotation	Dissolved air bubbles through the contaminated media to carry low density solids (particles) to surface for collection.	Not usually applicable to dissolved VOCs, more applicable to free-floating oils.
		Reverse Osmosis	High pressure forces water through specially constructed membrane leaving the contaminant behind.	Not applicable because it results in a large volume of wastewater that requires treatment.
		Ultra-filtration	Similar membrane separation process as reverse osmosis but can separate organics of a subcolloidal nature, as well as colloidal and particulate matter.	Not applicable to the contaminants found in groundwater at the site (does not reduce toxicity).
		Electro-dialysis	Another membrane separation process that uses electrical current rather than pressure as the driving force.	Not applicable to the containments found in groundwater at the site (usually applicable to water containing dissolved salts).
		Freeze Crystallization	Process by which certain solutes crystallize out from a saturated solution cooled to freezing temperatures.	Not applicable to the contaminants in the groundwater at the site.
		Thin-film Evaporation	Volatiles are separated in a multi-stage evaporator.	Not applicable due to much higher costs than other physical treatment. Technology meant for semi-solids (paints).

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (continued)	Biological Degradation (continued)	Aerated Lagoons	Biodegradation in an aerated surface pond.	Not applicable because of need for large undeveloped land area.
		Aerobic Composting	Waste stream fed to silo or aerobic digester on surface.	Not applicable; requires high solids content.
		Land Treatment	Collected waste stream applied to soils with addition of nutrients and bacteria to induce aerobic biodegradation.	Not applicable because of need for large undeveloped land area with appropriate soils.
		PACT TM Treatment	Activated carbon plus biological degradation in an aerobic environment.	Not applicable because of potential for disruption of process due to high metals concentrations, lack of nutrients to maintain activity of microorganisms, relatively low and variable organics concentrations.
		Mutant Bacteria	Genetically altered bacteria used in an aerobic treatment process.	Not applicable because of potential for disruption of process due to high metals concentrations, lack of nutrients to maintain activity of microorganisms, relatively low and variable organics concentrations.

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
<div> <div>Treatment (continued)</div> <div> <div>Biological Degradation (continued)</div> <div> <div>Chemical Treatment</div> <div> <div>Precipitation/Coagulation/Flocculation</div> <div>pH Adjustment</div> <div>Oxidation/Reduction</div> <div>Hydrolysis</div> <div> <div> <div>peroxidation</div> <div>UV (Photo) Oxidation</div> </div> </div> </div> </div> </div> </div> <div>2-23</div>	Biological Degradation (continued)	Fluidized Bed Reactors	Microorganisms used for degradation in a fluidized bed.	Not applicable (relatively new and unproven technology).
		Anaerobic Digestion	Degradation of organics in an oxygen-free environment.	Not applicable because of potential for disruption of process due to high metals, concentrations, lack of nutrients to maintain activity of microorganisms, relatively low and variable organics concentrations.
		Precipitation/Coagulation/Flocculation	Chemical equilibria altered to reduce the solubility of the contaminants; polymers added to promote flocculation.	Potentially applicable.
		pH Adjustment	pH adjusted for further treatment or discharge.	Potentially applicable as pretreatment.
		Oxidation/Reduction	Appropriate chemicals added to either raise or lower oxidation state of reactant.	Not applicable because of the type of contaminants present.
		Hydrolysis	Chemical decomposition by hydrolytic reactions.	Not applicable due to selective hydrolysis of certain compounds and generation of secondary wastes.
		UV (Photo) Oxidation	Combination of ozone and ultraviolet oxidation of hazardous constituents resulting in contaminant breakdown.	Not applicable due to generation of secondary wastes, selective oxidation of certain compounds, and need for a continuous ozone supply.

what secondary wastes?
 converts to H_2O & CO_2
 combine w/
 acid extraction

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (continued)	Physical Treatment (continued)	Liquid-to-Liquid Solvent Extraction	Dissolution of contaminants in a liquid solvent.	Not applicable due to chemical requirements, implementability, cost considerations, and generation of secondary wastes.
		Liquid-Aerosol Solvent Extraction	Dissolution of contaminants in an aerosol or atomized solvent.	Not applicable, see comments for liquid-to-liquid solvent extraction.
In Situ Treatment	Biological Treatment	Biodegradation	System of injection and extraction wells to introduce nutrients and an oxygen source to degrade contamination.	Not feasible due to the variety of inorganic and organic chemicals in the groundwater.
		Chemical Reaction	System of injection and extraction wells to inject chemical reagents to treat contamination.	Not applicable due to a variety of chemical constituents--causes migration under uncontrolled conditions, and creates unmanageable waste products.
	Incineration	Permeable Treatment Beds	Trenches placed perpendicular to groundwater flow to treat groundwater as it passes by.	Not applicable (unproven technology).
		Various Thermal Destruction Techniques	Basic purpose of all techniques is to reduce the volume and/or toxicity of organics in the wastewater by exposing it to high temperatures.	Not applicable because concentrations of organics in groundwater are too low and volume is too high to be cost effective.
Discharge	Disposal/Discharge	POTW	Extracted water discharged to local POTW.	Potentially applicable.
		Deep Well Injection	Extracted water discharged to deep well injection.	Not applicable because the cost will be much higher than for injection, with no additional benefit.

Not Organic metals

TABLE 2-4. INITIAL SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

Groundwater General Response Action	Remedial Technology	Process Options	Description	Screening Comments
<div>Discharge (continued)</div>	<div>Disposal/ Discharge (continued)</div>	<div>Reinjection Wells</div>	<p>Extracted and treated water recharged back to the aquifer through a series of reinjection wells.</p>	Potentially applicable.
		<div>Surface Water</div>	<p>Extracted and treated water discharged to surface water in the vicinity of the sites.</p>	Potentially applicable.
		<div>Streams Offsite</div>	<p>Extracted and treated water discharged to streams offsite.</p>	Potentially applicable.
	<div>Offsite Disposal/ Discharge</div>	<div>RCRA/TSCA Permitted</div>	<p>Contaminated groundwater or hazardous treatment byproducts transported to an offsite RCRA TSD facility for treatment.</p>	Potentially applicable for residuals of treatment process only.

The following list of general response actions and the corresponding migration control process options meet the initial screening criteria:

- No-Action/Institutional Action Response
 - Groundwater monitoring
- Plume diversion
 - Vertical slurry wall
 - Relocation of Pricketts Brook
- Collection of groundwater
 - Extraction wells
- Subsequent onsite treatment
 - Chemical treatment (pH adjustment and precipitation/coagulation/ flocculation)
 - Physical treatment (filtration, carbon absorption, ion exchange, and air stripping)
- Discharge of treated groundwater
 - Publicly owned treatment works
 - Groundwater reinjection
 - Surface water

Chapter 3 further evaluates the process options on the basis of effectiveness and implementability. In addition, the relative capital and operation and maintenance costs are presented, based on engineering estimates.

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- Dames and Moore, 1980. Investigation for the New Jersey Court on " Feasibility and Advisability of containment and Removal of Contaminated Groundwater and Soils in the Pricketts Brook Watershed, Middlesex County, New Jersey and, if Feasible and Advisable, Recommended Methods for accomplishing Such Objectives.

3. EVALUATION AND SELECTION OF PROCESS OPTIONS AND THE DEVELOPMENT AND SCREENING OF ALTERNATIVES

In this chapter, a two-part analysis is performed to develop specific remedial alternatives from the range of process options that emerged from the screening exercise in Chapter 2. The first step in this process is a detailed evaluation of each process option, which address criteria for effectiveness, ease of implementation, and cost. Process options are then combined as potential remedial alternatives, which in turn are evaluated using these same criteria.

3.1 EVALUATION AND SELECTION OF PROCESS OPTIONS

This section presents the evaluation, selection, and a brief description of the process options that passed the initial screening in Chapter 2. These options are:

- No-action/institutional action response
 - Groundwater monitoring
- Plume diversion
 - Vertical slurry wall
 - Relocation of Pricketts Brook
- Collection of groundwater
 - Extraction wells
- Subsequent onsite treatment
 - Chemical treatment (pH adjustment and precipitation/coagulation/flocculation)
 - Physical treatment (filtration, carbon adsorption, ion exchange, air stripping)
- Discharge of treated groundwater
 - Publicly owned treatment works
 - Groundwater reinjection
 - Surface waters.

The process options are evaluated using the following criteria:

- Effectiveness--The evaluation of the potential effectiveness of options relative to other processes within the same technology type is conducted on the basis of their capacity to handle estimated volumes of media of concern (contaminated groundwater), their ability to achieve remedial action objectives, and the potential impacts to human health and the environment during the construction and implementation phase, to demonstrate reliability for the contaminants of concern.
- Implementability--The evaluation of implementability is based on the technical and institutional feasibility of the option's design, construction, and operation.
- Cost--The evaluation of an option's cost is based on the relative capital and operation and maintenance (O&M) costs, rather than on detailed estimates.

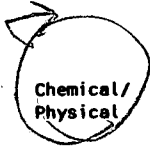
During the evaluation process, an option's effectiveness is the primary concern, with implementability and costs being secondary concerns. These same criteria are used to screen remedial alternatives later in this chapter.

The process option evaluation is shown in Table 3-1. This table presents a summary of the options that passed the initial screening in Chapter 2 and the associated technologies and responses. The evaluation is conducted in a flowchart format with separate sections for comments on effectiveness, ease of implementation, and cost.

3.1.1 No Action/Institutional Action

Monitoring is selected as the no-action/institutional response, as shown in Table 3-1. Monitoring would be used to evaluate plume migration and the possible future impact on the downgradient water supply wells. Groundwater monitoring is

TABLE 3-1. EVALUATION OF SCREENED PROCESS OPTIONS FOR MANAGEMENT OF MIGRATION ALTERNATIVES

Response Action	Technology Type	Process Options	Effectiveness	Implementability	Cost
No Action/ Institutional Actions	Monitoring	Increased monitoring at and near Base supply wells	Effective for documenting and evaluating site conditions and contaminant migration; does not satisfy remedial action objectives to reduce mobility, toxicity, or volume of contaminants.	Readily implementable, but in itself, does not meet or satisfy State/local government requirements.	No capital, moderate O&M
Containment	Vertical Barriers	Soil-Bentonite Slurry Walls	Effective in controlling plume migration.	Readily implemented.	Low capital, no O&M.
		Cement-Bentonite Slurry Walls	Effective in controlling plume migration when structural strength is also required.	Readily implemented.	Moderate capital, no O&M.
		Rerouting Pricketts Brook	Effective in controlling plume migration.	Readily implemented.	Moderate capital, no O&M.
Collection	Pumping	Extraction Wells	Effective and reliable groundwater extraction method.	Readily implemented.	Low capital, low O&M.
Treatment	 Chemical/ Physical	pH Adjustment	May be required to adjust pH for efficient operation of subsequent processes.	Readily implemented.	Low to moderate capital and O&M.
		Filtration	May be required to protect subsequent processes from suspended solid or colloidal material.	Readily implemented.	Moderate capital, low O&M.
		Air Stripping	Effective and reliable for VOC reduction. Used upstream of activated carbon to reduce loading.	Readily implemented.	Moderate capital, low to moderate O&M.
		Activated Carbon	Effective and reliable for VOC, hydrocarbon, and lead reduction. High lead loading may limit service life of carbon.	Readily implemented.	Moderate capital and O&M.
		Ion Exchange (Sorption Resins)	Effective and reliable for lead and organic contaminant reduction.	Readily implemented.	Moderate capital and O&M
Discharge and Disposal	On-site/ Near-site Discharge	Reinjection Wells	Effective and reliable discharge method.	Readily implemented. Must meet NJPDES substantive requirements.	High capital, moderate O&M.
		POTW	Effective and reliable discharge method.	Readily implemented. Discharge permit required.	Moderate capital, low O&M.
		Discharge to Surface stream	Effective and reliable discharge method.	Readily implemented. Must meet NJPDES substantive requirements.	Moderate capital, low O&M.

performed using existing wells with the option for additional well construction if necessary. This process is effective for documenting and evaluating site conditions and for determining migration patterns, but it does not satisfy any of the remedial action objectives. Monitoring is easily implemented and has low capital costs and moderate operation and maintenance (O&M) costs, depending on the sampling frequency.

3.1.2 Containment

A vertical slurry wall was selected as a potential containment response action. A soil-bentonite wall in a crescent shape constructed through Pricketts Pond was selected as the process option to contain the plume migration. A slurry wall would be effective for this application because of its low permeability relative to the adjacent soils, resistance to attack by incompatible chemicals, low capital costs, and practically no O&M costs. While this process option may be effective in limiting the migration of contaminants beyond their current extent, it is not effective in reducing the risk posed to public health or the environment, and provides no treatment for the contaminants present.

Relocation of Pricketts Brook is selected as a second containment response option that involves the construction of a new 3,000 foot long by 35 foot wide channel (concrete-lined or unlined) south of the current stream bed and backfilling the existing stream bed. This action would be taken to negate the hydraulic influence of Pricketts Brook on groundwater recovery as part of remediation. The channel would have moderate capital costs and extremely low O&M costs.

Containment process options must be combined with collection/treatment/discharge/disposal options to meet remedial objectives.

3.1.3 Collection

Extraction wells are selected as the appropriate process option for intercepting and extracting contaminated groundwater. This option is effective as a companion process to containment by helping to reduce contaminant concentration in groundwater, thereby reducing its toxicity. Extraction wells may be installed and operated with low capital and O&M costs.

3.1.4 Treatment

The goal of treatment process options is the removal of contaminants from groundwater. The treatment of groundwaters may (1) reduce the threat posed to public health and the environment, and (2) serve as a necessary step to meet action-specific applicable or relevant and appropriate requirements (indirect discharge permit requirements or substantive New Jersey Pollutant Discharge and Elimination System [NJPDDES] permit requirements).

pH adjustment with precipitation has been selected as a potential process option for chemical treatment because it is a proven technology for removal of metals from wastewater streams and is (operationally) a relatively simple unit treatment process. The process is reliable, provided in-process pH monitoring is used. The process has low to moderate capital and O&M costs.

Filtration is a potential process option selected as a companion process for chemical treatment. Granular media filtration may be used either as pretreatment to protect those

processes that are vulnerable to fouling by suspended solids (e.g., activated carbon and ion exchange), or as a polishing step subsequent to metals precipitation (ensuring that fines are removed from the treated wastewater). The filtration equipment generally consists of a fixed bed of granular particles (e.g., sand and/or anthracite coal) that may be gravity fed or pressurized. Filtration is a common treatment process with moderate capital and low O&M costs.

Air stripping has been selected as a potential process option for physical treatment because it is a proven and effective technology for removal of volatile organic compounds (VOCs). Air stripping is a mass transfer process in which volatile organic contaminants are stripped from water by contact with air and therefore transferred to a gaseous phase. In general, air flows in a counter-current direction to the water flow. The air-to-water mass ratio depends on the contaminants to be removed. This air-to-water ratio, which dictates equipment size and the optimum operating parameters, is a direct function of the contaminant vapor pressure, solubility in water, and percent removal required. The capital costs for air stripping treatment are moderate. The O&M costs are low unless the ambient air temperature is below 40° F and heating is required. If heating is required, the O&M costs become moderate. The off gas from the air stripping unit is usually treated by gas-phase granular activated carbon (GAC). Air stripping, when used to reduce VOC loading on aqueous phase GAC or sorptive ion exchange columns, can result in significant cost savings over the use of aqueous phase GAC or ion exchange alone. For example, for the same level of contaminants, gas-phase GAC for air stripping would have four to five times the service life as for aqueous phase GAC alone.

Aqueous phase GAC has also been selected as a potential process option for physical treatment. In contacting VOC-contaminated groundwater, organics are selectively adsorbed by the activated carbon that is generally placed in a series of packed columns. In addition to organics removal, some inorganic compounds, such as arsenic, lead, and mercury, have successfully been removed by this process. Generally, 1 percent total organic carbon in the wastewater influent to the process is considered an upper load limit. Air stripping is frequently used upstream of the GAC column to remove the volatile components and reduce the organic loading to the GAC column. GAC treatment is an established and proven technology and the equipment is readily available. Both capital and O&M costs are moderate.

Ion exchange has been selected as another potential process option for physical treatment. Ion exchange, using cation exchange resins, has been proven effective in selectively removing metals, such as zinc, lead, and cadmium. Water containing various levels of contaminants is passed either in a downflow or upflow direction in a column packed with resin specifically designed for this waste stream. While cation exchange resins would remove many metals from contaminated groundwater, anion exchange resins can be designed to remove contaminant anions from groundwater. Resins can also be designed to remove a wide range of polar and nonpolar organics. Ion exchange systems are readily available and are well established technology. Capital and O&M costs are moderate.

3.1.5 Discharge Options

Discharge to the local publicly owned treatment works (POTW) has been selected as one of the feasible discharge options. Discharge to a POTW is an effective and reliable discharge method, and has low capital and O&M costs. In considering

discharge to a POTW, two option-specific considerations must be evaluated. First, it must be determined whether the POTW is in compliance with NJPDES and pretreatment program requirements. If the POTW is found to be out of compliance, the discharge to a POTW would be prohibited in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act Section 121(d)(3). Second, the POTWs permitting requirements need to be investigated since discharge to a POTW is considered an offsite disposal option subject to the POTWs permitting requirements. These considerations may affect the implementability of this option.

Reinjection wells have been selected as another potential discharge option by which the treated groundwater is reinjected into the Old Bridge Aquifer. This discharge alternative would be beneficial for minimizing any potential impact of incrementally increased saltwater intrusion into the shallow aquifer when removal of contaminated groundwater for treatment is implemented. Reinjection of treated groundwater would likely require increased removal of contaminants over levels required for POTW discharge, resulting in high capital and moderate O&M costs.

While reinjection is a proven technology, implementation problems may be encountered. As stated previously, the Old Bridge Aquifer ranges from 0 to 5 feet in depth. The shallowness of this Aquifer may represent technical difficulties, as fluidization of the soil may result. Reinjection of treated groundwater would have to meet the substantive requirements of NJDEP permitting programs. Treatment levels required by the NJDEP are established on a case-by-case basis. Projected treatment levels employed in this analysis are drinking water standards.

Surface water discharge onsite is the third potential discharge option. Surface discharge is an effective and reliable discharge method, is readily implementable, and has moderate capital and low O&M costs. Discharge to surface waters onsite would have to comply with the substantive requirements of the NJPDES program.

3.1.6 Disposal

Offsite disposal is selected to address any solid hazardous byproducts of groundwater treatment processes, such as spent activated carbon, filtration media, or aqueous solutions or resins themselves from regeneration of ion exchange columns. This process can be implemented with a moderate-to-high cost, resulting from compliance with Resource Conservation and Recovery Act requirements, long-distance transportation and disposal charges.

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3.2 DEVELOPMENT AND SCREENING OF ALTERNATIVES

In developing remediation alternatives, the process options are combined to address site-specific conditions, effectiveness, technical and institutional ease of implementation, and costs. The screening of alternatives takes place as remedial alternatives are found to be less effective in addressing site needs, or when costs can not be justified.

3.2.1 Development of Alternatives

Table 3-2 presents a summary of five remedial alternatives under consideration. These alternatives are derived from the process options that resulted from Chapter 2. As can be seen from the table, the alternatives consider various levels of treatment and discharge options.

TABLE 3-2. SUMMARY OF MANAGEMENT OF MIGRATION ALTERNATIVES

Technology Type/ Process Option	Remedial Alternative Area or Volume	1	2	3	4	5
		No Action	Treatment (metals), POTW Discharge	Treatment (metals & organics), POTW Discharge	Treatment (metals & organics), Discharge to Surface Water	Treatment (metals & organics), Reinjection
Groundwater Monitoring	Entire area of Contaminated Plane Plus Additional Area Down- gradient Toward Public Water Supply Wells	0	0	0	0	0
Remediation Wells	Entire Area of Contaminated Plume		0	0	0	0
Slurry Wall at Down- gradient Edge of Contaminated Plume	Entire Area of Contaminated Plume		0	0	0	0
Relocation of Pricketts Brook	Entire Area of Contaminated Plume		0	0	0	0
pH Adjustment, Precipitation	Entire Area of Contaminated Plume		0	0	0	0
Filtration	Entire Area of Contaminated Plume			0	0	0
Air Stripping	Entire Area of Contaminated Plume			0	0	0
Activated Carbon	Entire Area of Contaminated Plume				0	0

TABLE 3-2. SUMMARY OF MANAGEMENT OF MIGRATION ALTERNATIVES (Continued)

Technology Type/ Process Option	Area or Volume	1 No Action	2 Treatment (metals), POTW Discharge	3 Treatment (metals and organics), POTW Discharge	4 Treatment (metals and organics), Discharge to Surface Steam	5 Treatment (metals and organics), Reinjection
Ion Exchange	Entire Area of Contaminated Plume				0	0
Discharge to POTW	Entire Area of Contaminated Plume		0	0		
Discharge to Surface Stream	Entire Area of Contaminated Plume				0	
Reinjection	Entire Area of Contaminated Plume					0

3.2.2 Screening of Alternatives

The preliminary screening of alternatives is essential when selecting a set of alternatives for detailed evaluation. This phase of the FS allows alternatives to be examined for applicability prior to the detailed analysis (presented in Chapter 4). Screening at this stage involves three steps--refinement, evaluation, and selection.

Alternatives are first refined through examination of:

- Potential areas or volumes of material to be treated
- Estimates of sizes and capabilities of process options that comprise the alternative
- Treatment rates
- Spatial requirements for equipment and treatment facilities
- Disposal quantities and hauling distances for treatment byproducts
- Required permits or substantive regulatory requirements
- Limitations imposed on the alternative by site conditions and restriction of future land use.

Once refined, alternatives are then evaluated by their short-term and long-term effectiveness, implementability, and cost. The content of each of these criteria is the same as the evaluation of process options conducted earlier in this chapter. In this phase, however, combinations of process options are being evaluated and the level of detail is greater. Effectiveness and implementability pertain to specific target levels and technical requirements, respectively. The cost evaluation of an alternative is highly dependent on site-specific characteristics, such as the size of the contaminated groundwater plume and specific contaminants present. The costs associated with these

remedial alternatives may be compared initially by estimating costs on a normalized basis. Groundwater treatment costs are evaluated assuming a 400 gallons per minute (gpm) capability for each of the alternatives. Alternatives having order-of-magnitude greater costs than other alternatives, but that are not significantly more effective or feasible, are eliminated in this screening stage. Alternatives that indicate a potentially high performance level are retained for detailed analysis.

Table 3-3 presents the results and the management of migration alternatives evaluation with respect to effectiveness, implementability, and cost. Although additional data collection will be needed prior to design for each pump and treatment alternative, the cost for developing this data has not been estimated and is not included in this evaluation. All of the technologies described in Table 3-3 have been demonstrated and fully proven. Treatment process construction, reliability, and health and safety issues are well known and manageable. As such, these issues are not considered in the screening process. Refinement of the alternatives is discussed in the following subsections.

3.2.2.1 No Action

Alternative 1 is the No-Action alternative, which utilizes groundwater monitoring at selected points. Quarterly monitoring at a total of 33 monitoring wells is assumed for plume migration characterization (NJDEP 1988). There are no capital costs for Alternative 1. The O&M costs (for monitoring) are estimated at \$60,000 annually.

TABLE 3-3. EVALUATION AND SCREENING OF ALTERNATIVES

Description	Effectiveness	Implementability	Cost
<u>Alternative 1 - No Action Monitoring</u>	Does not reduce toxicity, immobility, or volume of contaminants.	Readily Implemented.	Capitol: \$0 O&M \$60,000
<u>Alternative 2 - Downgradient Slurry Wall, Relocation of Pricketts Brook, Groundwater Pump and Treat (with Madison Industries process wastewater) Discharge to POTW: pH Adjustment and Precipitation of Metals</u>	Reduces risk to acceptable levels by removing contaminants before they reach public drinking water wells. Separates contaminants to a sludge that can be handled appropriately. If source remains controlled will result in permanent cleanup. High short- and long-term.	Technically and administratively feasible. Does not restrict future land use or groundwater use. effectiveness	Capitol: \$2,100,000 O&M: \$700,000 (400 gpm flow assumed.
<u>Alternative 3 - Downgradient Slurry Wall, Relocation of Pricketts Brook, Groundwater Pump and Treat, Discharge to POTW: Air Stripping, \$1,200,000 pH Adjustment and Precipitation of Metals</u>	Reduces risk to acceptable levels by removing contaminants before they reach the public drinking water wells. Separates contaminants to a sludge and to spent carbon, both of which (400 gpm flow can be handled appropriately. If source remains controlled, will result in permanent cleanup. High short- and long-term effectiveness.	Technically and administratively feasible. Does	Capitol: \$3,100,000 not restrict O&M: future land or groundwater use. assumed.

TABLE 3-3. EVALUATION AND SCREENING OF ALTERNATIVES (Continued)

Description	Effectiveness	Implementability	Cost
<u>Alternative 4 - Downgradient Slurry Wall, Relocation of Pricketts Brook, Groundwater Pump and Treat, Discharge to Surface Stream:</u> Air Stripping, pH Adjustment and Precipitation of Metals, and Granular Activated Carbon	Reduces risk to acceptable levels by removing contaminants before they reach public drinking water wells. Separates contaminants to a sludge and to spent carbon, both of which can be handled appropriately. If source remains controlled, will result in permanent cleanup. High short- and long-term effectiveness.	Technically and administratively feasible. Does future land or groundwater use.	Capitol: \$5,800,000 not restrict O&M: \$1,900,000 (400 gpm flow assumed).
<u>Alternative 5 - Downgradient Slurry Wall, Relocation of Pricketts Brook, Groundwater Pump and Treat, Discharge to Reinjection:</u> Air Stripping, pH Adjustment and Precipitation of Metals, Granular Activated Carbon, and Ion Exchange	Reduces risk to acceptable levels by removing contaminants before they reach public drinking water wells. Removes contaminants to a sludge, spent carbon, and ion exchange, regeneration wastes, all of which can be handled appropriately. If source remains controlled, will result in permanent cleanup. High short- and long-term effectiveness.	Technically and administratively feasible. Does not restrict future land or groundwater use. Reinjection to Old Bridge Aquifer may present implementation problems.	Capitol: \$4,500,00 O&M: \$2,000,000 (400 gpm flow assumed)

3.2.2.2 Treatment for Metals Removal Featuring Discharge to POTW

Alternative 2 is the recommended remedial action presented in the Court Order issued in New Jersey in April 1988. This proposed remediation plan includes the installation of three recovery wells in the plume of contamination; construction of a crescent-shaped slurry wall downgradient of the plume of contamination; relocation of Pricketts Brook; discharge to the Middlesex County Utilities Authority (MCUA) treatment plant in Sayreville, New Jersey, through the Old Bridge Township Sewerage Authority (OBTSA) collection system from two recovery wells; and 80-percent zinc reduction in the discharge from the third recovery well that would be combined with Madison Industries process wastewater prior to discharge to the MCUA through the OBTSA.

The slurry wall would be constructed of a soil-bentonite slurry and keyed into the South Amboy Fire Clay. The estimated depth of the South Amboy Fire Clay in the area of the contaminated plume is 30 to 70 feet. The slurry wall would be installed across Pricketts Pond. A typical slurry wall width ranges between 2 to 4 feet.

The recovery wells would be designed for extraction depths exceeding 20 feet. This well depth is appropriate for homogenous aquifers such as the Old Bridge Aquifer, with high hydraulic conductivities and with pumping capacities ranging from 25 to 3,000 gpm. The typical components of a deep well are a screen, casing, filter pack and seal, and pump.

Of the three recovery wells, one well located at the upgradient end of Pricketts Pond would be designed to withdraw groundwater at a rate of approximately 300 gpm, while the two wells located farther upgradient would be designed for

approximately 50 gpm each. The water pumped from the larger and one of the smaller recovery wells would be discharged to MCUA through OBTSAs without treatment, assuming that the appropriate permits and approvals can be obtained.]??

The water pumped from the second smaller well, designated T-1 in the Court Documents (NJDEP 1988), would be mixed with the process wastewaters generated by the Madison Industries and pretreated for 80-percent zinc reduction prior to discharging to MCUA through the OBTSAs industrial sewer line. As part of the discharge system described in the Court Order, a secured metering and sampling vault would be designed and approved by MCUA and OBTSAs.

pH adjustment is used for metals removal for this alternative. The pH adjustment system consists of storage, reaction, and settling tanks equipped with agitators and delivery systems and pH monitoring equipment.

For Alternative 2, the capital costs are estimated at \$2,100,000, and the O&M costs are estimated at \$700,000 annually.

3.2.2.3 Treatment for Metals and Organics Removal and Discharge to POTW, Surface Waters, or ReInjection

Alternatives 3, 4, and 5 all include the proposed construction of a crescent-shaped slurry wall downgradient of the contaminant plume, relocation of Pricketts Brook, and extraction of the contaminated groundwater through the use of remediation wells. Differences in the level of treatment for metals and organic contaminants and the discharge of treated groundwater vary and are discussed in the following paragraphs.

Alternative 3 includes pH adjustment, followed by metals precipitation, filtration, and air stripping; the treated

effluent is discharged to the MCUA. Filtration is provided both as a means of removing fines (thereby allowing for better metals removal) and also as a necessary preliminary step to air stripping. Dual filter units are proposed to allow for continuous treatment operation during filter backwash cycles. Granular activated carbon is proposed (for all alternatives employing stripping) to capture airborne organic vapors venting from stripping operations. Disposal of the spent GAC is an additional consideration. In order to optimize treatment efficiency, treatability pilot testing of the groundwater is recommended as part of the design activities.

For alternative 3, capital costs are estimated at \$3,100,000 and O&M costs at \$1,200,000 annually.

Alternative 4 is identical to alternative 3, except that air stripping is followed by a two column GAC system. Effluent from the air stripper would be pumped to the lead column, which, when exhausted would be replaced by the secondary column. The GAC adds a polishing step for better organics removal, which is necessary for onsite discharge to surface waters (it is assumed that drinking water standards would need to be met).

For alternative 4, capital costs are estimated at \$5,800,000, and annual O&M costs are estimated at \$1,900,000.

Alternative 5 is identical to alternative 4 except that multiple columns of cation exchange resin are added as a polishing step for improved metals removal prior to reinjection. Multiple columns are proposed to allow for efficient regeneration of the resin without disruption of the treatment process. The application of this technology is highly specific to a given waste stream and requires predesign treatability testing.

For alternative 5, capital costs are estimated at \$4,500,000, and annual O&M costs are estimated at \$2,000,000.

3.2.2.4 Screening Summary

Based on the evaluation of alternatives conducted in this chapter, all alternatives with the exception of the no-action alternative would be effective in reducing the public health risk to acceptable levels. Capital and O&M costs were compared as a potential basis for screening out alternatives that were an order of magnitude higher and that had little or no increased effectiveness. None of the alternatives included in this evaluation were deleted because of implementability or cost considerations.

4. DETAILED ANALYSIS OF ALTERNATIVES

This chapter presents a detailed analysis of the alternatives that were developed in Chapter 3. This analysis consists of three phases. First the alternatives are further refined with respect to volumes or areas of the operable unit (i.e., contaminated groundwater), the technologies and process options to be used, and the performance capabilities and requirements of the technologies or operations. Second, an assessment and summary of each alternative is performed against the following evaluation criteria:

- Short-term effectiveness with respect to protection of the public, workers, and the environment during implementation and the estimated time period until remedial response objectives are achieved
- Long-term effectiveness and permanence, including assessment of residual risks, adequacy of residual management controls, and reliability of those controls
- Performance of the remedial alternative in reducing mobility, toxicity, and volume of contaminants; amounts of hazardous materials to be treated; and the degree of reductions, as a percentage, in toxicity, mobility, and volume of contaminants
- Implementability with respect to the technical feasibility of construction and operation, reliability, ease of undertaking additional future actions and monitoring, administrative feasibility, and availability of services and materials
- Capital and operation and maintenance costs to an accuracy of -30 to +50 percent, if possible
- Compliance with chemical-, action-, and location-specific ARARs and any other guidelines pertinent to the site contaminants
- Overall protection of human health and the environment, based on the previous criteria

- State acceptance
- Community ~~or appropriate body~~ acceptance.

The third phase consists of a comparative analysis to assess the performance of alternatives, relative to each other, with respect to the evaluation criteria of the second stage.

4.1 ALTERNATIVES ANALYSIS

The alternatives included in this analysis are: no-action; treatment of groundwater, in combination with Madison Industries process wastewater, for metals prior to discharge to the publicly owned treatment works (POTW); treatment of the contaminated groundwater from ^(A)metals and organics prior to discharge to the POTW; and treatment for both metals and organics, with discharges to surface waters and to reinjection. Groundwater monitoring is necessary for all alternatives. Actions common to all but the no-action alternative are relocation of Pricketts Brook, installation of a downgradient slurry wall at the leading edge of the contaminant plume, and removal of groundwater from the plume by pumping.

4.1.1 Alternative 1--No-Action Alternative

For this alternative, contaminated groundwater is left in place; monitoring is the only action taken. A minimum of 33 wells (including 3 extraction wells) are assumed to be monitored, ~~as detailed in the April 1988 Order from the Superior Court of New Jersey (NJDEP 1988)~~. The monitoring program includes the monitoring of 33 wells and quarterly sampling for analysis on cadmium, copper, lead, zinc, and volatile organics. As shown in the detailed analysis for this alternative (see Tables 4-1 and 4-2), the no-action alternative does not reduce mobility,

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TABLE 4-1. DETAILED ANALYSIS OF ALTERNATIVES — THRESHOLD CRITERIA

Criteria	Alternative 1 No Action	Alternative 2 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Discharge to POTW	Alternative 3 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, Discharge to POTW	Alternative 4 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, GAC, Surface Water Discharge	Alternative 5 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, GAC, Ion Exchange, Reinjection
OVERALL PROTECTIVENESS					
Human Health Protection					
Groundwater Ingestion for Existing Users	No reduction in risk.	Reduces overall excess lifetime cancer risk to less than 10^{-4} by pump and treat, therefore is protective of human health.	See Alternative 2.	See Alternative 2.	See Alternative 2.
Groundwater Ingestion for Future Users	No reduction in risk.	Reduces overall excess lifetime cancer risk to less than 10^{-4} by pump and treat, therefore is protective of human health. Saltwater intrusion may be a concern.	See Alternative 2.	See Alternative 2.	See Alternative 2. Mitigates possible saltwater intrusion concerns.
Environmental Protection	Allows continued contamination of groundwater.	Migration of contaminated groundwater curtailed by pump and treat. Saltwater intrusion may be a concern.	See Alternative 2.	See Alternative 2.	See Alternative 2. Mitigates saltwater intrusion concerns.
COMPLIANCE WITH ARARS					
Chemical-Specific ARARs	Contaminated plume does not meet groundwater standards.	Contaminated plume would meet MCLs in greater than 12 years, depending on extraction rate.	Contaminated plume would meet MCLs in 12 years.	See Alternative 3.	See Alternative 3.
Location-Specific ARARs	Not relevant. There are no location-specific ARARs.	See Alternative 1.	See Alternative 1.	See Alternative 1.	See Alternative 1.
Action-Specific ARARs	Would not meet ARARs.	Would meet POTW discharge requirements with decreased pumping rate.	Would meet POTW discharge requirements without decreased pumping.	Would meet NJPDES discharge requirements without decreased pumping.	Would meet projected groundwater reinjection requirements without decreased pumping.
Other Criteria and Guidance	May allow ingestion of groundwater exceeding 1×10^{-4} risk level.	Protects against groundwater ingestion at 10^{-4} level.	See Alternative 2.	See Alternative 2.	See Alternative 2.

Where is the calculation?

Formula activated carbon

There aren't any?

TABLE 4-2. DETAILED ANALYSIS OF ALTERNATIVES — PRIMARY CRITERIA

Criteria	Alternative 1 No Action	Alternative 2 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Discharge to POTW	Alternative 3 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, Discharge to POTW	Alternative 4 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, GAC, Surface Water Discharge	Alternative 5 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, GAC, Ion Exchange, Reinjection
LONG-TERM EFFECTIVENESS AND PERMANENCE					
Magnitude of Residual Risk					
— Groundwater Ingestion for Existing Users	Future risk greater as plume migrates to public water supply wells. Eventually natural attenuation and dilution may decrease risk.	Risk eliminated by extracting groundwater exceeding 10^{-4} overall excess lifetime cancer risk levels. Safe drinking levels to be achieved in greater than 12 years, depending on flow and assuming source is controlled.	Same as Alternative 2, except that safe drinking levels achieved in 12 years, assuming 400 gpm and source is controlled.	See Alternative 3.	See Alternative 3.
— Groundwater Ingestion for Future Users	Risk greater as area of contamination increases. Eventually natural attenuation and dilution may decrease risk.	Risk eliminated by extracting groundwater exceeding 10^{-4} overall excess lifetime cancer risk levels. Safe drinking water achieved in greater than 12 years depending on flow and assuming source is controlled. Saltwater intrusion may be a concern.	Same as Alternative 2, except that safe drinking water achieved in 12 years, assuming 400 gpm and source is controlled. Saltwater intrusion may be a concern.	See Alternative 3.	See Alternative 3.
Adequacy and Reliability of Controls	No controls over contamination. No reliability.	Groundwater extraction adequately controls contaminated groundwater. Groundwater pump and treat is reliable.	See Alternative 2.	See Alternative 2.	See Alternative 2. Reinjection may cause saturation of surface soils.
Need for Periodic Review (at 5 year intervals or less)	Review would be required to ensure adequate protection of human health and the environment.	See Alternative 1.	See Alternative 1.	See Alternative 1.	See Alternative 1.
SHORT-TERM EFFECTIVENESS					
Community Protection	Contaminated groundwater may reach public drinking water wells.	Potential impact during construction of the slurry trench and relocation of Pricketts Brook.	See Alternative 2.	See Alternative 2.	See Alternative 2.
Worker Protection	No significant risk to workers.	Protection required against dermal contact, vapor inhalation during operation of treatment system.	See Alternative 2.	See Alternative 2.	See Alternative 2.

TABLE 4-2. DETAILED ANALYSIS OF ALTERNATIVES — PRIMARY CRITERIA (Continued)

Criteria	Alternative 1 No Action	Alternative 2 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Discharge to POTW	Alternative 3 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, Discharge to POTW	Alternative 4 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, GAC, Surface Water Discharge	Alternative 5 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, GAC, Ion Exchange, Reinjection
SHORT-TERM EFFECTIVENESS Continued					
Environmental Impacts	Continued impact from existing conditions.	Aquifer drawdown during groundwater extraction.	See Alternative 2. Air stripping may impact air quality, although vapors will be removed from discharge using GAC.	See Alternative 3.	Aquifer restored by reinjection. Air stripping may impact air quality, although vapors will be removed from discharge using GAC.
Time Until Action is Complete	Not applicable.	Groundwater remedial action may require more than 12 years depending on flow and assuming source is controlled.	Groundwater remedial action complete in 12 years assuming 400 gpm and source is controlled.	See Alternative 3.	See Alternative 3.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT					
Treatment Process Used	None.	Precipitation of metals from groundwater.	Precipitation of metals and air stripping of organics in groundwater.	See Alternative 3. Treatment with the addition of granular activated carbon as polishing step for organics.	See Alternative 4. Ion exchange added as a polishing step for metals.
Amount Destroyed or Treated	None.	Reduction to level of metals acceptable to POTW.	Reduction of metals and organics to levels acceptable to POTW.	Reduction of metals and organics to levels acceptable for surface water discharge.	Reduction to levels of metals and organics acceptable on reinjection.
Reduction of Toxicity, Mobility, or Volume	None.	Volume and toxicity of contaminated groundwater is reduced.	See Alternative 2.	See Alternative 2.	See Alternative 2.
Irreversible Treatment	None.	Precipitation of metals irreversible with removal of sludge for offsite disposal at RCRA permitted facility.	Same as Alternative 2. Air stripping is irreversible with regeneration of carbon used for air stream treatment.	Same as Alternative 3 with granular activated carbon regeneration.	See Alternative 4 with ion exchange requiring regeneration.
Type and Quantity of Residuals Remaining After Treatment		Sludge from precipitation of metals requires disposal offsite.	Sludge from precipitation of metals requires disposal and carbon from gaseous treatment requires regeneration.	Same as Alternative 3 with granular activated carbon from aqueous treatment requiring regeneration.	See Alternative 4 with ion exchange requiring regeneration.
Statutory Preference for Treatment	Does not satisfy.	Satisfies.	Satisfies.	Satisfies.	Satisfies.

TABLE 4-2. DETAILED ANALYSIS OF ALTERNATIVES — PRIMARY CRITERIA (Continued)

Criteria	Alternative 1 No Action	Alternative 2 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Discharge to POTW	Alternative 3 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, Discharge to POTW	Alternative 4 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, GAC, Surface Water Discharge	Alternative 5 Downgradient Slurry Wall, Relocation of Pricketts Brook, Precipitation of Metals, Air Stripping, GAC, Ion Exchange, Reinjection
IMPLEMENTABILITY					
Ability to Construct and Operate	No Construction or Operation.	Onsite groundwater treatment requires operation. Downgradient slurry trench may be somewhat difficult to construct.	Similar to Alternative 2.	Similar to Alternative 2.	Similar to Alternative 2. Reinjection may be difficult due to shallow water table.
Ease of Doing Move Action if Necessary	If monitoring indicates remedial action is necessary, may need to perform another FS/ROD.	Simple to extend groundwater extraction system and to increase treatment system capacity. Industrial sewer line capacity may be limited.	See Alternative 2.	Complete Alternative. Can handle variable volume and concentration. Simple to extend groundwater extraction system and increase treatment system capacity for greatly increased scope of remedial action.	See Alternative 4. Capacity for reinjection may be limiting factor.
Ability to Monitor Effectiveness	Monitoring program to detect plume movement in direction of public water supply wells.	Proposed monitoring should give early notice of failure before any significant exposure can occur.	See Alternative 2.	See Alternative 2.	See Alternative 2.
Ability to Obtain Approvals and Coordinate With Other Agencies	No approval necessary except for monitoring procedures.	Agreement to accept treated water must be negotiated with local POTW and Sewer Authority. Permit may be required.	See Alternative 2.	Need to demonstrate that NJPDES requirements are met or obtain NJPDES permit depending on final location of discharge.	Need to demonstrate that New Jersey underground injection requirements are met.
Availability of Services and Capacities	None required except for monitoring well sampling and analysis, which are readily available.	Need treatment plant operators.	See Alternative 2.	See Alternative 2.	See Alternative 2.
Availability of Equipment, Specialists, and Materials	Sampling, analytical equipment, specialists, materials are readily available.	Same as Alternative 1. Also need treatment plant operators. Treatment plant equipment readily available.	See Alternative 2.	See Alternative 2.	See Alternative 2.
Availability of Technologies	Sampling and analytical technologies readily available.	Technologies well developed and available. Treatability testing recommended.	See Alternative 2.	See Alternative 2.	See Alternative 2.
COSTS					
Capital Costs	0	\$2,100,000	\$3,000,000	\$5,700,000	\$4,300,000
First-Year Annual O&M Costs	\$60,000	\$ 700,000	\$1,100,000	\$1,800,000	\$2,000,000
Present Worth Cost (4-12 years implementation and 2 years additional monitoring)	\$490,000	\$7,500,000	\$11,300,000	\$20,000,000	\$19,000,000

toxicity, or the volume of contaminants; has a high short-term and low long-term effectiveness; and is readily implemented.

This alternative does not reduce the risk associated with the plume of contaminated groundwater and does not meet chemical- or action-specific applicable or relevant and appropriate requirements (ARARs). There are no location-specific ARARs. Frequent review of groundwater monitoring data would have to be made to ensure that contaminants were not moving so close to the public drinking water system downgradient of this site that they could not be captured by groundwater pumping and treatment systems without impacting the public water supply wells. The lead time needed to implement a groundwater pump and treatment system would likely negate any advantage to be gained by using this approach. There are no capital costs associated with this alternative because existing wells are used for monitoring. Monitoring (operation and maintenance [O&M]) costs would be estimated at \$60,000 annually. The details of all evaluation criteria are presented in Tables 4-1 and 4-2.

4.1.2 Alternative 2--Treatment for Metals, Discharge to POTW

This alternative consists of installing a downgradient slurry wall at the leading edge of the contaminant plume, relocating Pricketts Brook, pumping contaminated groundwater from the shallow aquifer, treating the groundwater to remove metals using pH adjustment and precipitation, and discharging the treated water to Middlesex County Utilities Authority (MCUA) through the existing industrial sewer line (Old Bridge Township Sewer Authority [OBTSA]). This alternative was designed to follow, as closely as feasible, the Court Order that was signed in April 1988 for cleanup of this contaminated groundwater plume.

Differences between this alternative and the Court Order are discussed in the following paragraphs.

The Court-ordered alternative of pumping and routing 50 gallons per minute (gpm) of contaminated groundwater to Madison Industries for a minimum of 80-percent zinc removal and 350 gpm directly to the POTW without treatment is not a feasible alternative without some modification. Assuming that MCUA sets limits comparable to those for the Kin-Buc Land Fill, the discharge from the CPS/Madison site will be required to meet a zinc limitation of 0.66 milligrams per liter (mg/l) and a copper limitation of 0.36 mg/l. Based on the current average zinc and copper concentrations in the Old Bridge Aquifer, all 400 gpm of pumped groundwater must be treated. In addition, the assumption was made that all 400 gpm of contaminated groundwater will be treated in a new system rather than utilizing any existing treatment equipment that Madison may currently have onsite.

Madison's process wastewater effluent from zinc chloride production is currently required to meet pretreatment standards for existing sources for inorganic chemicals manufacturing point source discharges, zinc chloride subcategory, 40 CFR Part 415.674. Limits are established for:

	<u>Daily Maximum (mg/l)</u>	<u>Monthly Average (mg/l)</u>
Arsenic (T)	3.0	1.0
Zinc (T)	2.3	0.76 mg/l
Lead (T)	0.18	0.048

These standards are based on the use of lime addition for metals (precipitation), clarification, pH adjustment, and dual media filtration. These treatment technologies are proposed for Alternative 2 groundwater cleanup.

It is not expected that Madison's existing treatment system would be capable of handling the additional treatment load. Typical wastewater flow rates from zinc chloride production are less than 10 thousand gallons per day (gpd), which are considerably smaller than the 400 gpm (approximately 500,000 gpd) cleanup flow assumed. Since the costs associated with extensive retrofitting of existing systems often exceed costs of new systems, it is assumed (for cost purposes) that a new treatment system would be installed.

Additional features of this alternative were taken from the April 1988 Court Order without modification. They include the installing three pumping wells, as discussed in Wehran (1983); installing a downgradient slurry wall at the leading edge of the contaminated groundwater plume; rerouting Pricketts Brook; and monitoring the Old Bridge Aquifer. *drawn*
P

Extraction wells are assumed to be placed so that capture of the contaminant plume would be maintained. Wehran (1983) discusses location of three extraction wells such that the largest would be placed near the upgradient end of Pricketts Pond and designed to pump 300 gpm and two smaller wells would be placed upgradient of the first well and designed to pump at 50 gpm each (for a total pumping rate of 400 gpm). Groundwater modeling was used (Wehran 1983) to determine that this pumping scenario would capture the plume. Based on this reference, this pumping scenario is assumed for plume capture, with the provision made in the April 1988 Court Order that the wells have the capability to pump twice the rate needed for plume capture, or 800 gpm. Predesign investigations would be necessary for optimization of a number of wells, their locations, and pumping rates. A soil-bentonite slurry wall would be constructed to help

contain the contamination for subsequent pumping and treatment. The wall would be crescent shaped, approximately 1,000 feet long and as much as 70 feet deep downgradient of the contaminated area (keyed in to the confining layer). The approximate location of the slurry wall would be across Pricketts Pond, one third its length from the upgradient end. Predesign investigation is also necessary to determine whether the South Amboy Fire Clay is substantial and to determine the precise location, length, and depth of the slurry wall.

To minimize hydrologic impact on the groundwater removal system, Pricketts Brook would be rerouted south of the contaminated area (Wehran 1989). This involves constructing a 3,000 foot long by approximately 35 foot wide channel and backfilling the existing Brook. A reinforced concrete lining was not included in the existing construction costs of the channel. Flow will not be increased over the existing rates and therefore, should not present a problem, requiring such a lining. Relocation of the existing Brook may necessitate regrading of drainage areas to prevent runoff from leaving the site in an uncontrolled state.

The Brook will be rerouted to discharge into the down-gradient end of Pricketts Pond, which is consistent with the intended purpose of minimizing the hydrologic impact of the groundwater removal system.

Monitoring for this alternative would follow the April 1988 Court Order. Sampling would include 30 monitoring wells and 3 extraction wells. The sampling program would begin 1 month before startup of the pumping and treatment system; with sampling 1 month after system startup; additional sampling 3 months after system startup; and quarterly sampling thereafter, continuing up

to 2 years after shutdown of the pumping and treatment system (following attainment of target cleanup levels in the groundwater). Samples would be analyzed for cadmium, copper, lead, zinc, and volatile organics. The analysis for volatile organics would include the organics previously identified in the list of 13 indicator compounds for which target cleanup levels have been established.

The discharge of treated groundwater to the POTW must meet ordinance and permitting requirements of the MCUA. Currently, MCUA does not have specific numerical discharge limitations in its ordinance. As such, limitations applicable to this site would likely be determined by MCUA based on best professional judgement, provided that MCUA agrees to accept the groundwater. A similar situation in Middlesex County, the Kin-Buc Landfill, has been used as a model of anticipated limitations (see Table 4-2). Metal limitations are the same as, or close to, pretreatment standards for electroplaters and metal finishers for all pollutants, and as such, treatment requirements should not entail more sophisticated methods than lime addition, settling, clarification, and pH adjustment.

Major post-treatment costs associated with an indirect discharge to the POTW include the construction of a line to tap into the sewer main, monitoring requirements, and MCUA permit and user fees.

Sewer line construction options include gravity sewers to either the old OBTSa interceptor (onsite) or the MCUA main interceptor, or a force main to the MCUA interceptor. Discharge to the OBTSa interceptor is assumed for this alternative.

An important consideration for this alternative is whether the total toxic volatile organics mass limitation (0.1 pounds per hour total volatile organic compounds [TVOC]) projected for POTW discharge can be met at the assumed flow of 400 gpm. Preliminary calculations indicate that to meet these limitations for organics, groundwater that is not treated for organics (as is the case in this scenario) could only be discharged at up to 175 gpm. Additionally, a recent letter from OBTSa has raised concern that this sewer line may not have the capacity to handle an additional flow as high as 400 gpm (OBMUA 1988). Therefore, consideration for implementing this alternative will have to include the possible restriction in flow to 175 gpm, thus reducing the pumping rate and increasing the time needed to clean up the contaminated plume. Predesign investigation would be needed to determine if pumping at 175 gpm would capture the entire contaminant plume. Lack of system flexibility to handle any increased flow would also be a drawback.

As shown in the detailed analysis, Tables 4-1 and 4-2, this alternative reduces mobility, toxicity, and volume of contaminants; has moderate short-term and long-term effectiveness; and is readily implemented. Groundwater would be removed from the Old Bridge Aquifer until the target cleanup levels (see Table 2-1) are reached; therefore, Alternative 2 would provide a reduced risk and would comply with ARARs.

The capital costs for Alternative 2 are estimated at \$2,100,000, and the O&M costs are estimated at \$700,000 annually. Major engineering assumptions included in the evaluation of Alternative 2 are as follows:

- Slurry wall dimensions are 1,000 feet long by 70 feet deep.

- Unlined channel is 3,000 feet long by 35 feet wide for relocation of Pricketts Brook south of its existing channel and backfill of the existing Brook channel.
- For groundwater removal, construction of 3 wells with a total capacity of 800 gpm to approximately a 70 foot depth with alarms, controls, piping, instrumentation and pumps (including a spare 300 gpm pump) is included in the estimate of capital costs. Monitoring of 33 wells would take place, as detailed in previous discussions of this Alternative.
- For treatment, 1,000 feet of piping to treat, line addition for pH adjustment, and multimedia filtration flow of 400 gpm.
- For POTW discharge, 500 feet of piping to discharge point, a POTW service charge of \$0.10/1,000 gallons of treated water discharged, and monthly monitoring for eight metals and volatile organic compounds (VOCs).
- For sludge from metals precipitation, manifesting, transporting, and disposal in a permitted hazardous waste landfill--1,000 tons per year.

The details of all evaluation criteria for Alternative 2 are presented in Tables 4-1 and 4-2.

4.1.3 Alternative 3--Treatment for Metals and Organics, Discharge to POTW

Alternative 3 includes installing a downgradient slurry wall at the leading edge of the contaminant plume, relocating Pricketts Brook, pumping contaminated groundwater from the Old Bridge Aquifer, treating groundwater to remove metals and organics (this alternative does not combine groundwater with Madison Industries' process wastewaters), and discharging treated water to the MCUA through the existing industrial sewer line (OBTSA).

This alternative is identical (with regard to treatment technologies proposed) to Alternative 2 with the addition of air stripping for the removal of organic contaminants prior to discharge to the MCUA. This alternative represents an attempt to decrease the anticipated flow restriction that would be placed on Alternative 2, based on meeting the anticipated mass limitation of 0.1 pounds per hour for total toxic volatile organics. As a general assumption, increased flow would result in a decreased time for cleanup. Assuming a higher flow would be allowed based on the reduction in total volatile organics discharged from treatment, the issue of OBTSA line capacity would only remain for flows approaching the 400 gpm assumed for this alternative.

As shown in the detailed analysis for this alternative, Tables 4-1 and 4-2, this alternative reduces mobility, toxicity, and volume of contaminants; has a high short-term and a high long-term effectiveness; and is readily implemented.

As for Alternative 2, groundwater would be removed from the Old Bridge Aquifer until the target cleanup levels (see Table 2-1) are reached; therefore, Alternative 3 would provide an acceptable risk level and would comply with ARARs.

The capital costs for Alternative 3 are estimated at \$3,000,000, and the O&M costs are estimated at \$1,100,000 annually. Major engineering assumptions included for the evaluation of Alternative 3 follow:

- Slurry wall dimensions are 1,000 feet long by 70 feet deep.
- Unlined channel is 3,000 feet long by 35 feet wide for relocation of Pricketts Brook south of its existing channel and backfill of the existing Brook channel.

- For groundwater removal, construction of three wells with total capacity of 800 gpm to approximately 70 foot depth with alarms, controls, piping, instrumentation, and pumps (including a 300 gpm spare pump) is included in the estimate of capital costs. Monitoring of 33 wells, as detailed for Alternative 2.
- For treatment, 1,000 feet of piping to treatment, lime addition for precipitation of metals followed by multimedia filtration and air stripping. For air stripping, dual columns are assumed, stripping factor of 5.0, change in pressure of 0.5 feet and 99 percent removal of volatile organics. Gaseous phase activated carbon is assumed for removal of organics from gaseous discharge from airstrips. Flow of 400 gpm.
- For POTW discharge, 500 feet of piping to discharge point, a POTW service charge of \$0.10/1,000 gallons of treated water discharged, and monthly monitoring for eight metals and VOCs.
- For sludge from metals precipitation, manifesting, transporting, and disposing in a hazardous waste landfill approximately 1,000 tons per year.

The details of all evaluation criteria are presented in Tables 4-1 and 4-2.

4.1.4 Alternative 4--Treatment for Metals and Organics, Discharge to Surface Water

Alternative 4 consists of installing a downgradient slurry wall at the leading edge of the contaminant plume, relocating Pricketts Brook, pumping contaminated groundwater from the Old Bridge Aquifer, treatment to remove metals and organics, and discharge of treated water to the relocated Pricketts Brook Substantive New Jersey Pollutant Discharge Elimination System (NJPDES) requirements for the onsite discharge would have to be met.

This alternative features the same treatment unit processes as for Alternative 3 with the addition of a polishing step for organics using granular activated carbon (GAC) in anticipation of stringent NJPDES requirements. This alternative has the potential for removing, treating, and discharging flows at higher than the 400 gpm assumed, if State requirements allow. The relocated channel for Pricketts Brook would be lined with reinforced concrete for this alternative as a protective measure for increased flows from discharge of treated water.

Specific NJPDES requirements for an onsite discharge would be based on negotiations with the State and on the best professional judgement of the State permit writers. It is assumed that the State would want CPS/Madison Industries to treat contaminated groundwater to meet maximum contaminant levels for drinking water in accordance with the New Jersey Safe Drinking Water Act (NJSDWA) and amendments. For pollutants not regulated by NJSDWA, target cleanup levels (see Table 2-1) are assumed.

Discharge is assumed to be to the relocated, reinforced concrete-lined channel of Pricketts Brook. The relocated Brook channel would be 3,000 feet long by 35 feet wide. The abandoned channel of Pricketts Brook would be backfilled. The relocated channel would discharge to the downgradient end of Pricketts Pond.

As shown in the detailed analysis for this alternative, Tables 4-1 and 4-2, this alternative reduces mobility, toxicity, and volume of contaminants; has a high short-term and a high long-term effectiveness; and is readily implemented. As for Alternatives 2 and 3, groundwater would be removed from the Old Bridge Aquifer until the target cleanup levels (see Table 2-1)

are reached; therefore, Alternative 4 would reduce the risk to acceptable levels and would comply with ARARs.

The capital costs for Alternative 4 are estimated at \$5,700,000, and the O&M costs are estimated at \$1,800,000 annually. Major engineering assumptions included in the evaluation of Alternative 4 follow:

- Slurry wall dimensions are 1,000 feet long by 70 feet deep.
- Reinforced concrete-lined channel is 3,000 feet long by 35 feet wide for relocation of Pricketts Brook to the south of its existing channel and backfill of the existing Brook channel.
- For groundwater removal, construction of 3 wells with total capacity of 800 gpm to approximately a 70 foot depth with alarms, controls, piping, instrumentation, and pumps (including a 300 gpm spare pump) is included in the estimate of capital costs. Monitoring of 33 wells to take place, as detailed for Alternative 2.
- For treatment, 1,000 feet of piping to treatment, lime addition for precipitation of metals followed by multimedia filtration, air stripping, and GAC. Flow of 400 gpm. For air stripping, dual columns are assumed, stripping factor of 5.0, change in pressure of 0.5 feet, and 99-percent removal of volatile organics. Gaseous phase activated carbon is assumed for removal of organics from gaseous discharge of air stripper. Removal and replacement of spent activated carbon by vendor. Flow assumed at 400 gpm.
- For discharge to the relocated channel of Pricketts Brook, 500 feet of piping and monthly monitoring for eight metals and VOCs.
- For disposal of all process solid wastes, manifesting, transporting, and disposing in a permitted hazardous waste landfill approximately 1,000 tons per year.

The details of all evaluation criteria are presented in Tables 4-1 and 4-2.

4.1.5 Alternative 5--Treatment for Metals and Organics, Discharge to ReInjection to the Old Bridge Aquifer

Alternative 5 consists of installing a downgradient slurry wall at the leading edge of the contaminant plume, relocating Pricketts Brook, pumping contaminated groundwater from the Old Bridge Aquifer, treating groundwater to remove metals and organics, and discharging treated water to the Old Bridge Aquifer through reinjection.

This alternative is identical to Alternative 4 with the exception that an ion exchange is added to further reduce the metals concentrations, and treated groundwater is discharged to the shallow aquifer upgradient of the contaminated plume. The relocated channel of Pricketts Brook would be unlined, because it would not be used for discharge of treated water. The major reason for including this alternative was to minimize any impact of groundwater removal on the shallow aquifer by replacement. Reinjection wells may not be successfully implemented because of the small unsaturated zone at the site and the occurrence of inverse conical depressions that may fluidize the soil and flood the ground surface. For purposes of this study, it is assumed that groundwater may be successfully reinjected to the Old Bridge Aquifer.

Development and periodic redevelopment of an injection well is necessary to maintain efficiencies because they do not continue to develop themselves with use as extraction wells do.

The system design includes a determination of the number of wells needed, the patterns and spacing of the wells, the design of the individual wells, the pumping cycles and rates needed, and the method of handling discharges.

Prior to designing the well system, a complete hydrogeologic understanding of the site must be established. A potentiometric surface map (i.e., a map depicting contours of equal head) and a geologic cross section of the site should be created. Development of these two tools is very important to well system design. Other parameters that are required for system design are the coefficients of transmissivity (T) and storage (S) and discharge (Q) and drawdown ($H-h_w$) from pump tests. Once data on these parameters are established, the design process can proceed.

A predesign investigation is recommended to determine the exact location, number, spacing, and other design parameters.

As shown in the detailed analysis (see Tables 4-1 and 4-2), this alternative reduces mobility, toxicity, and volume of contaminants; and has a high short-term and a high long term effectiveness, but may not be readily implemented. As for Alternatives 2, 3, and 4, groundwater would be removed from the Old Bridge Aquifer until target cleanup levels (see Table 2-1) are reached; therefore, Alternative 5 would reduce the risk to an acceptable level and would comply with ARARs.

The capital costs for Alternative 5 are estimated at \$4,300,000, and the O&M costs are estimated at \$2,000,000 annually. Major engineering assumptions included in the evaluation of Alternative 5 are as follows:

- Slurry wall dimensions are 1,000 feet long by 70 feet deep.
- Unlined channel is 3,000 feet length by 35 feet width for relocation of Pricketts Brook to the south of its existing channel and backfill of the existing Brook channel.

- For groundwater removal, construction of three wells with total capacity of 800 gpm to approximately a 70 foot depth with alarms, controls, piping, instrumentation, and pumps (including a 300 gpm spare pump) is included in the estimate of capital costs. Monitoring of 33 wells to take place, as detailed for Alternative 2.
- For treatment, 1,000 feet of piping to treatment, line addition for precipitation of metals followed by multimedia filtration, ion exchange, air stripping, and GAC. Flow of 400 gpm. For air stripping, dual columns are assumed, stripping factor of 5.0, change in pressure of 0.5 feet, and 99-percent removal of volatile organics. Gaseous phase activated carbon is assumed for removal of organics from gaseous discharge of air stripper. Removal and replacement of spent activated carbon by vendor.
- For reinjection of treated water, controls, instrumentation, piping, and pumps.
- For disposal of all process solid wastes, manifesting, transporting, and disposing in a hazardous waste landfill approximately 1,000 tons per year.

The details of all evaluation criteria are presented in Tables 4-1 and 4-2.

4.2 COMPARISON AMONG ALTERNATIVES

The purpose of this comparative analysis is to evaluate the advantages and disadvantages of the alternatives relative to each other and the seven criteria used in the detailed assessment. This procedure contrasts with the detailed analysis of each alternative where each alternative was analyzed with little consideration given to comparison among alternatives. The comparative analysis allows for the identification of items that can be evaluated by the decision-maker during the final selection. Short- and long-term effectiveness; toxicity, mobility and volume reductions; implementability; and costs receive the greatest consideration, whereas overall protection

and compliance with ARARs were examined as threshold determinations in consideration of the alternatives' viability. Discussions for this section refer to Tables 4-1 and 4-2, for evaluation of the Threshold Criteria and Primary Criteria, respectively.

4.2.1 Threshold Criteria

4.2.1.1 Overall Protectiveness

All but the no-action alternative meet this threshold criterion for reducing the risk to acceptable levels by removing contaminated groundwater from the upper aquifer. For Alternatives 2 through 5, the overall excess lifetime cancer risk for ingestion of contaminated groundwater and inhalation of vapors is projected to be less than 1×10^{-4} . These four alternatives will achieve target cleanup levels, comply with State and Federal ARARs, and provide overall protectiveness for human health.

Among the four pump and treatment alternatives, the only significant differences in protectiveness are the rates at which contaminated groundwater may be removed from the upper aquifer. Preliminary assessment has shown that groundwater removal rates for Alternatives 2, 3, and 5 may be reduced from the assumed removal rate of 400 gpm. Reasons for reducing removal rates include the following:

- For Alternative 2, discharge to the POTW will likely have a mass limitation for volatile organics over time. Therefore, based on groundwater monitoring data, discharge (and, consequently, the removal rate) will have to be somewhat less than 400 gpm to meet this discharge limitation. In addition, the industrial sewer line at the site may not have adequate capacity for a 400-gpm discharge, according to the local sewer authority.

- For Alternative 3, discharge to the POTW is treated for both metals and organics. Therefore, flow will not have to be reduced below 400 gpm based on a mass limitation for organics. The limited capacity of the industrial sewer line at the site may create the need for reducing flow to less than 400 gpm, however.
- For alternative 5, discharge to reinjection may have to be reduced to less than 400 gpm based on the rate at which treated water can feasibly be reinjected to the shallow aquifer.

The projected removal rate for Alternative 4 remains at 400 gpm; any technical reasons for limiting this rate are not readily apparent.

4.2.1.2 Compliance With ARARs

As discussed in the previous section, all but the no-action alternative comply with State and Federal ARARs. For chemical-specific ARARs, Alternatives 2 through 5 are projected to achieve target cleanup levels for the contaminant plume, which will result in an overall excess lifetime cancer risk of less than 1×10^{-4} , based on hypothetical exposure scenarios.

For action-specific ARARs, Alternatives 2 through 5 will meet projected limitations for POTW discharge (Alternatives 2 and 3), NJPDES requirements (Alternative 4), and projected NJPDES requirements based on best professional judgement of the New Jersey Department of Environmental Protection permit writer for reinjection of treated water (Alternative 5).

4.2.2 Primary Criteria

4.2.2.1 Long-Term Effectiveness and Permanence

This criterion addresses the results of a remedial action in terms of risk remaining at the site after response objectives have been met. Residual human health risks following remediation and adequacy and reliability of controls to manage treatment residuals and untreated wastes remaining at the site are included in this criterion.

The pump and treatment systems for Alternatives 2 through 5 are projected to achieve target cleanup levels for the contaminant plume, and will, therefore comply with State and Federal ARARs and be protective of human health. The overall excess lifetime cancer risk for ingestion of groundwater from the contaminant plume following remediation is projected to be less than 1×10^{-4} .

For Alternatives 2 through 5, groundwater extraction adequately controls the contaminated groundwater plume. Groundwater pumping and treatment is a reliable control method for contaminated groundwater. For Alternative 5, reinjection has the potential to saturate soils at the ground surface.

Containment methods used for these alternatives include a crescent-shaped slurry wall located between the leading edge of the contaminant plume and the public water supply wells, and relocation of Pricketts Brook. The slurry wall should better prevent the migration of contaminants to the public wells than would groundwater extraction alone. Assuming that the South Amboy Fire Clay is continuous and the slurry wall is keyed into it, the slurry wall is expected to provide adequate and reliable

control of contaminant migration, and is a reliable control method. Relocation of Pricketts Brook should reduce the quantity of water that is likely to infiltrate to the shallow aquifer, and as such, does not provide a large degree of control, nor is it expected to be highly reliable in its intended purpose (Geraghty and Miller 1987).

4.2.2.2 Short-Term Effectiveness

This criterion addresses protection of human health and the environment during construction and implementation and until the cleanup target level is achieved. For the no-action alternative, potential impacts to the community are contaminated drinking water, if the contaminated plume reaches the public water wells and/or continued existing environmental impacts. For Alternatives 2 through 5, community (potential impact during construction of the slurry trench and relocation of Pricketts Brook) and worker protection (protection required against dermal contact and vapor inhalation during operation of treatment system) are roughly equivalent. For Alternatives 2 through 4, the primary environmental impact will be from aquifer drawdown during groundwater extraction; for Alternative 5, reinjection of treated water would help alleviate this impact in addition to minimizing any potential for saltwater intrusion. A secondary environmental impact for Alternatives 3 through 5 may be to air quality from air stripping, even though vapors will be removed from this discharge using granular activated carbon.

In 1983, Wehran estimated the time until target levels are achieved at 12 years, assuming a flow rate of 400 gpm and 4 pore volumes of water to be treated. The most recent groundwater monitoring data (Wehran 1989) indicate some movement of the contaminated plume suggesting that a larger volume of groundwater

may now have to be treated. It is recommended that the estimate of time needed to achieve target concentrations be investigated in more detail as part of a predesign effort. Such an investigation would serve to provide both an updated estimate using current groundwater monitoring data and target concentrations and provide an estimate based on specific chemical characteristics. Lacking a more definitive estimate of time needed to achieve target concentrations, however, the 1983 values for the extraction rate at 400 gpm and time at 12 years are used for this feasibility study. Groundwater extraction is likely to be less than 400 gpm for Alternative 2, based on the need to meet projected discharge limitations for organics and the capacity of the industrial sewer line onsite. Groundwater extraction may be less than 400 gpm for Alternative 3 because of the industrial sewer line capacity and for Alternative 5 because of the feasibility of reinjecting this flow into the small unsaturated zone at this site. For Alternative 4, no reduction of the projected 400 gpm extraction rate is anticipated. Therefore, the time until remedial action is complete may be greater than the projected 12 years for Alternatives 2, 3, and 5 because of potential limitations on the rate at which groundwater is removed.

4.2.2.3 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1 does not reduce the toxicity, mobility, or volume of contaminated groundwater, and does not meet the statutory preference for treatment. Alternatives 2 through 5 reduce the volume and toxicity of contaminated groundwater and, with appropriate handling and disposal of residuals (e.g., sludge from precipitation of metals, spent carbon, ion exchange resins), will all meet the statutory preference for treatment.

4.2.2.4 Implementability

This criterion addresses the technical and administrative feasibility of implementing alternatives and the availability of various services and materials required during implementation. No construction or operation is needed for Alternative 1. Therefore, implementability of this alternative is relatively simple. Implementability of Alternatives 2 through 5 becomes increasingly difficult, based on the degree of treatment required, POTW permitting requirements, the complexity of treatment systems, and in the case of Alternative 5, the technical feasibility of reinjecting the entire flow to the upper aquifer. Alternative 5 appears to be the most difficult of the alternatives to implement.

4.2.2.5 Cost

The comparative analysis of costs discusses only differences in capital, O&M, and present worth values. Costs for each alternative have been provided in detail in Table 4-2. Generally, costs increase as technical complexity increases. Alternative 1 (monitoring) has an associated present worth of \$490,000. Alternative 2, the least complex treatment, has a present worth of \$7,500,000. Alternative 5, the most complex of treatment and discharge options, has a present worth of \$19,000,000. However, the highest present worth cost would be for Alternative 4 at \$20,000,000, primarily because of the assumption that the relocated Pricketts Brook would have to be lined for receiving the treated water discharge.

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